Reversing Underrepresentation:
The Impact of Undergraduate Research Programs on Enrollment in STEM Graduate Programs

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Introduction

Although more students are pursing graduate work in STEM disciplines than in years past, students from Black, Latino, and Native American backgrounds continue to be severely underrepresented in these programs, especially in comparison to their White and Asian American counterparts. Representing the fast growing sectors of our society, underrepresented racial minority (URM) students represent a great potential pool of advanced degree holders and researchers (Tsui, 2007). During the 2010-11 academic year, Native American, Black, and Latino students represented just 0.4%, 3.8%, and 4.1%, respectively, of all STEM graduate students (National Science Foundation & National Center for Science and Engineering Statistics, 2013).

Part of this underrepresentation is attributable to the lower probability that these students will complete STEM bachelor's degrees compared to their White and Asian peers (Hurtado, Eagan, & Hughes, 2012). The fact that so few underrepresented racial minorities enroll in (and complete) graduate programs in STEM is indicative of a persistent equity gap in STEM fields which compromises the country's ability to remain a leader in technology and innovation (President's Council of Advisors on Science and Technology, 2012).

To increase the participation of URM students in graduate STEM education, federal and private agencies have invested significantly in undergraduate research opportunities (DeHaan, 2005; Strayhorn, 2010). These research opportunities include both structured programs and research experiences outside of formal programs. Structured programs, such as Minority Opportunities in Research sponsored by NIH, may include assigned mentors, professional

development sessions, and stipends or tuition assistance. Other students gain undergraduate research experience by invitations from faculty or volunteering on faculty projects.

Students who access undergraduate research opportunities derive a number of immediate and long-term benefits from their participation. These benefits include improved confidence in research and professional skills, increased preparation for graduate school, and clarification on future career pathways (Craney et al., 2011; Hunter, Laursen, & Seymour, 2006; Luchini-Colbry, Wawrzynski, & Shannahan, 2013). Undergraduate researchers also tend to display a stronger interest in and commitment to pursuing a graduate program in STEM (Craney et al., 2011; Eagan et al., 2013; Hunter, Laursen, & Seymour, 2007; David Lopatto, 2004; Seymour, Hunter, Laursen, & DeAntoni, 2004). Previous research demonstrates that students who participate in research programs tend to attend graduate degree programs in the sciences at far higher rates than the students who do not (Slovacek, Whittinghill, Flenoury, & Wiseman, 2012).

Although several studies have examined the association between undergraduate research participation and students' post-college career and educational enrollment, few studies use a quasi-experimental design to account for selection bias in undergraduate research programs (Eagan et al., 2013; Slovacek et al., 2012). Slovacek et al. use propensity score matching (PSM) to account for endogeneity in the data to examine a set of outcomes associated with undergraduate research participation; however, their study uses a single-institutional sample. Eagan et al. also use PSM techniques; however, their study only examined how undergraduate research participation predicted *intentions* to enroll in STEM graduate programs. This study advances previous research by looking at the connection between undergraduate research participation and *actual enrollment* in STEM graduate and professional programs by using PSM techniques to analyze data from a national, longitudinal sample of STEM degree holders. This

study aims to provide evidence of the benefits of undergraduate research on subsequent STEM graduate and professional school enrollment for STEM bachelor's degree holders generally as well as specifically for URM STEM degree earners.

Benefits of Undergraduate Research

Black, Latino, and Native American students are severely underrepresented at the graduate level in STEM disciplines (National Science Foundation & National Center for Science and Engineering Statistics, 2013). Much of this underrepresentation echoes racial disparities in pre-college academic preparation and resources available to students to support them as undergraduates; however, these are not the only barriers faced by URM students. URM students also face obstacles in their undergraduate educational environment, including cultural and academic isolation, negative stereotypes, and low expectations, all of which contribute to lower levels of motivation and performance. Additionally, URM students pursuing STEM degrees have negative racial experiences that reduce their likelihood of persisting in STEM majors (Allen, 1992; Chang, Eagan, Lin, & Hurtado, 2011; Grandy, 1998; Nettles, 1998; Seymour & Hewitt, 1997).

Undergraduate research experiences (URE) have been shown to help URM students overcome many of these barriers. They inspire students (Villarejo et al., 2008), help them overcome racial isolation and other barriers in STEM (Gasiewski, Garcia, Herrera, Tran, & Newman, 2010), and facilitate stronger connections between students and their degree programs (Lopatto, 2003). UREs also provide a host of benefits that support a students' trajectory toward enrollment in a graduate STEM program. Engagement in undergraduate research appears to provide numerous personal, professional, and cognitive benefits for students who participate (Carter, Mandell, & Maton, 2009), though most of this literature appears to rely on student self-

report of these benefits (Sadler, Burgin, McKinney, & Ponjuan, 2010). These benefits include improved academic performance, strengthened technical and communication skills, increased self-confidence and self-efficacy in science, independent and/or creative thinking, and ability to handle ambiguity and obstacles (Hunter et al., 2007; Levis-Fitzgerald, Denson, & Kerfeld, 2005; Lopatto, 2007; Ward, Bennett, & Bauer, 2003). Research experiences in particular contribute to students' increased thinking like and acting as a scientist (Hunter et al., 2007), including understanding the research process in their field (Lopatto, 2007), the value of teamwork and collaboration in the scientific inquiry process (Hunter et al., 2007; Seymour et al., 2004), connecting concepts learned in the classroom to the real-world performance of science (Jackson & Moore, 2012; Levis-Fitzgerald et al., 2005; Villarejo et al., 2008), a sense of belonging in science (Villarejo et al., 2008), and an enhanced sense of science identity (Carlone & Johnson, 2007).

More intense gains experienced by URM students led Villarejo et al. (2008) to conclude that UREs are an especially effective tool to recruit and retain URMs in the STEM fields and turn them on to research careers. Ultimately, UREs give students insight into graduate study and career possibilities (Ward et al., 2003). Evidence suggests that the skills gained from undergraduate research continue to be important to students' in their positions in industry or as students in graduate school three years after the initial research experience (Russell, 2006).

Students' experiences with undergraduate research vary in structure, intensity, and the frequency or duration of the experience (Balster et al., 2010), all of which influence the level of gains student make as a result of being involved in research (Carter et al., 2009). Students who had research experiences spanning multiple semesters or summers tended to have stronger outcomes and learning gains and expressed more favorable attitudes toward research as a career

option after graduation than those with shorter term research experiences (Bauer & Bennett, 2003; Berkes & Hogrebe, 2007; Craney et al., 2011; Russell, 2006). Similarly, more time spent working in research laboratories was associated with a higher self-efficacy in science (Berkes & Hogrebe, 2007). Timing of a research experience matters as research experiences for more advanced students are more likely to sustain or confirm their interest in science rather than ignite an initial attraction to science, as they would for first- or second-year students (Lopatto, 2007). The actual research activities in which students are engaged also appear to matter. Students who collect or analyze data are more likely to have higher degree aspirations at the end of the summer than those who merely review prior literature (Strayhorn, 2010). Overall, research demonstrates that students who are more deeply immersed in research have higher satisfaction and report greater self perceived gains (Russell, 2006).

Strong faculty-student relationships are an essential component of effective undergraduate research experiences and help ensure that students reap the greatest advantages from their engagement in research (Craney et al., 2011; McGee & Keller, 2007). Students working in collaboration with other students and faculty agreed more strongly than students working on their own that participation in undergraduate research strengthened their interest in pursuing graduate study and were more interested in pursuing research as a career option (Craney et al., 2011). Indeed working closely with faculty on research can help overcome challenges associated with student background characteristics (e.g., poor academic preparation in high school) and can increase the quality and breadth of information to which students have access, especially with respect to educational options pose undergrad (Lundberg & Schreiner, 2004; Malcom & Dowd, 2012). The informal mentorship relationships that develop organically between student and faculty during research can be transformative to students' experiences (Kuh,

Kinzie, Cruce, Shoup, & Gonyea, 2006), particularly toward developing their intentions of enrolling in graduate school. Garibay, Hughes, Eagan, and Hurtado (2013) found the best predictors of students' choosing STEM graduate study over entering the workforce or graduate school in a different field were working with faculty on research and receiving support and mentoring from faculty.

Linking URE Participation to Graduate School Enrollment

Student narratives of their involvement in structured undergraduate research programs indicate that research introduced students to what science was and what the possibilities were for both graduate studies and scientific careers, which was important given students' lack of exposure to STEM careers (Gasiewski et al., 2010). Specifically, students overwhelmingly reported that research experiences helped increase their understanding of the purpose and benefits of attending graduate school (Carter et al., 2009; Ward et al., 2003), positively influenced their aspirations to attend graduate school (Russell, 2006), and helped define their career goals (Lopatto, 2003), namely by increasing their interest in science research careers (Russell, 2006). Alumni who completed research experiences reported that their involvement in research helped prepare them for graduate study and secure admission to graduate or medical school by boosting their academic credentials and providing them an advantage over their peers. They also reported that research experience enhanced skills that facilitated their transition to graduate study and ultimately helped them be successful as graduate students (Kozeracki, Carey, Colicelli, & Levis-Fitzgerald, 2006; Lopatto, 2003; Luchini-Colbry et al., 2013).

Participation in undergraduate research increases the odds that students later pursued graduate education (Bauer & Bennett, 2003; Hathaway, Nagda, & Gregerman, 2002), and research experiences of longer duration are associated with a more pronounced likelihood of

pursuing a PhD (Russell, Hancock, & McCullough, 2007). Participation in an on-campus, academic year research experience, for example, was associated with a substantial increase in the probability of pursuing a STEM PhD for high achieving and highly motivated minority students, even when controlling for demographic characteristics, precollege educational background, summer undergraduate research experiences, intended major, and parental educational attainment (Carter et al., 2009). In short, the studies above indicate that engagement in research increases students' excitement for STEM careers and increases the probability that students will continue to major in STEM, reach degree completion, and apply to graduate school in STEM.

In a study of alumni who had engagement experiences in undergraduate research, about half of the alumni planning to go on to biomedical Ph.D.s discovered their interest in science research *after* entering college (Villarejo et al., 2008). Specifically, of the 24 individuals who ultimately selected a biomedical PhD as their career goal, only 13 had considered research as a possible career choice at college entry. For the other 11 students, engagement in research was transformative and redirected students into a research career path when they had originally had no interest in pursuing that line of work upon college entry. The authors posit that undergraduate research might influence students' decision to enroll in graduate school in STEM both indirectly by bolstering achievement and students' résumés, which in turn make them more attractive candidates for graduate schools, and directly through encouraging students to consider a graduate career (Villarejo et al., 2008).

In response to the question as to whether a causal relationship exists between participation in research and pursuit of graduate study, in an experimental design study of a structured undergraduate research program at the University of Michigan, matched clusters of applicants were randomly assigned either to participate in a research program or to a control

group (Hathaway et al., 2002; Nagda, Gregerman, Jonides, von Hippel, & Lerner, 1998). Findings indicated that involvement in structured research experiences increased college completion rates, entry into graduate programs, and enrollment in doctoral or professional programs, especially among URM students. While these findings suggest a causal relationship, further evidence is needed to test this relationship across multiple institutions.

Underrepresented Students' Participation in Undergraduate Research

Given the plethora of benefits associated with research involvement, which students participate in research and what are their motivations for doing so? According to Russell's (2006) survey, 53% of all STEM majors participate in some form of independent or mentored undergraduate research (Russell, 2006), with only 7% participating in a research program sponsored by a national agency, such as NSF, NIH, or NASA, indicating that most research experiences occur through informal or local avenues. Precise participation rates vary within the different disciplines in STEM. Further, undergraduate researchers tend to be students with junior or senior standing, with URM students participating at equal or greater rates as their representations in the US population as a whole (Russell, 2006). Figueroa, Hughes, and Hurtado (2013) also found Black students to be over 16% more likely to participate in undergraduate research than their White peers. Undergraduate researchers also tend to have strong grade point averages (Russell, 2006), which is not surprising given that research programs generally prefer to select students who have a history of high academic achievement (Slovacek et al., 2012). High-achieving students likely already have the confidence and skills to navigate the academic system without additional help (Balster et al., 2010).

The reasons students cite for engaging in research vary. The top three reason students cited for choosing research engagement was to enhance their résumés, to gain practical

experience for a future career, and because it was a paid position (Luchini-Colbry et al., 2013). Further, 75% of students cited that they wanted to develop a mentoring relationship with a faculty member and another 71% thought the experience would help prepare them for graduate school (Luchini-Colbry et al., 2013). In contrast, in another study of 126 biology and chemistry undergraduates at universities and 4-year colleges across the country, a majority of students (74%) reported undertaking research primarily to learn *on their own* and because they want to help others; few students cited having a desire to author papers or engaging in research as a means to build their resume (Mabrouk & Peters, 2000).

Undergraduate Research Experiences as Communities of Practice

Sfard (1998) argues that two metaphors exist that can be used to describe learning. The first is learning as acquisition, very similar to Paolo Freire's (2000) concept of "banking education," where the teacher provides knowledge that the student receives, leading to the student's individual enrichment. STEM educators are very familiar with education as acquisition, as this metaphor can best be seen in the traditional methods by which introductory STEM courses are taught—extensive lecture, an emphasis on memorization and recall, and very little incorporation of active learning strategies (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012). Sfard instead points to a different metaphor for education that emphasizes community-building as an essential component of the learning process. In this second metaphor, education is considered to be participation, where both students and teachers are participants in a learning community and students are viewed more as apprentices of the teacher, who serves as the expert-participant. This metaphor views the educational process as one that invites students into a community of practitioners to which the teacher, as expert-participant already belongs. While this process can take place in the STEM classroom, learning as participation is even more

characteristic of STEM experiential learning opportunities, especially undergraduate research experiences. While Sfard concluded that neither metaphor is necessarily better than the other, both are likely essential to producing the type of deep learning that improves students' understanding.

In this sense, undergraduate research experiences can be conceptualized as communities of practice (Lave, 1991; Lave & Wenger, 1993; Wenger, 1998, 2000). In their work on situated learning, Lave and Wenger proposed that learning required engagement in what they termed "communities of practice." Communities of practice are defined along three dimensions: they involve some common enterprise, they form through mutual engagement among members, and they produce a shared wealth of resources that increase the capacity of the community to engage in its central activity. These resources typically arise out of the social relations that occur among members as they work together and include shared vocabulary, routines, culture, work styles, or sensibilities. Communities of practice can be informal, but they can also be extremely formal in organization, and are especially present within a group organized around some area of knowledge or a specific activity.

As such, both undergraduate research experiences and the broader STEM research community can be considered as communities of practice. Just as research has shown that research experiences can vary in terms of quality and level of authenticity, Lave and Wenger (1993) posited that participation in a community of practice means more than simply engaging in certain activities with certain people. Participation refers to a far more encompassing process of active participation in the activities of the community and the construction of an identity relative to that community. Resultantly, through studies of apprenticeships, Lave and Wenger demonstrated how participation in a community of practice happens through stages where a new

entrant begins participating at the periphery of the community, and as the entrant gains skills and knowledge, concomitant with increasing identification, the entrant begins moving closer to the center. Conceptualizing learning as participation in a community of practice then is more than just "learning by doing," but the situatedness of the process means full participation in the community, including the capacity to make contributions to the creation of meaning within that community.

Conceptualizing undergraduate research experiences as communities of practice supports the assertion that they help students develop a sense of STEM identity, resonant with Carlone and Johnson's (2007) science identity model. Science identity involves mastering competence of scientific concepts, opportunities for performance of scientific activities, and recognition by others within science as a science person. All of these are supported by Lave and Wenger's (1993) communities of practice framework; however, Lave and Wenger's framework would take these experiences one step further by postulating that, as students move closer to the center of the STEM research community of practice, they develop a greater sense of belonging in that community and thus aspire to opportunities to move even closer to the center of that community—essentially, to become a research scientist. To move closer to the center students would then be mentored by others within that community of practice to seek graduate study in STEM.

Methods

Data

Drawing from merged data from several national databases including longitudinal student data from the 2004 Cooperative Institutional Research Program's (CIRP) Freshman Survey (TFS) and the 2011 Post-Baccalaureate Survey (PBS), as well as institutional data from the

Integrated Postsecondary Educational Data System (IPEDS), this study examines the individual- and institutional-level factors that predict STEM bachelor's degree recipients' likelihood of matriculating into a STEM graduate/professional degree program relative within seven years of college entry. Our baseline sample came from the Cooperative Institutional Research Program's (CIRP) 2004 Freshman Survey (TFS), which was administered by the Higher Education Research Institute (HERI). The TFS asked freshman students about their demographic characteristics and academic backgrounds, their high school activities, their educational and career ambitions, and expectations of college. The National Institutes of Health (NIH) provided funds to target minority-serving institutions and institutions with NIH-sponsored undergraduate research programs to expand the traditional sample of colleges and universities that participate in the TFS. These funds provided an opportunity to administer the TFS to campuses that typically do not collect such data on their students.

In 2011, we collected additional information from students seven years after college entry to learn more about their educational and career pathways using the Post-Baccalaureate Survey. The 2011 PBS gathered information about participants' undergraduate experiences, perceptions, and posttest data on many of the attitudinal and behavioral items collected on the 2004 TFS. For this survey, we began with the original intended sample for the 2008 CSS, which included 240 institutions. HERI researchers then added all 2004 TFS respondents who had indicated on the TFS that they intended to pursue a STEM major and had enrolled at an institution that had provided degree information. Our final targeted sample for this survey was 66,080 students across 533 institutions. Of the 57,790 reachable participants, a total of 13,671 participants located across 500 undergraduate institutions responded to the survey, which resulted in a response rate of 23.7%. Additionally, in order to examine the relationship between institutional

characteristics and STEM bachelor's degree recipients' post-baccalaureate pathways, this study uses institutional data from IPEDS, which provides the most comprehensive data available on higher education institutions in the U.S.

From the longitudinal sample, we identified students who reported on the 2011 PBS that their undergraduate major was in a STEM discipline (see Appendix A for all majors defined as STEM), which included 7,649 students across 480 four-year colleges and universities. After removing cases that had yet to enter into a graduate program and were unemployed, our sample was further reduced to 7,331 students across 471 institutions.

Variables

The dependent variable in this study is a dichotomous variable representing whether STEM bachelor's degree recipients had entered into a STEM graduate or professional program by the summer of 2011. Appendix A has a list of the majors classified as STEM.

The primary independent variable of interest is whether students had participated in an undergraduate research program, and we measured research participation in three ways: participation in an undergraduate program, conducting research with faculty, and conducting research through a structured program and/or with faculty. We ran separate models to examine how sensitive our estimates were to the operationalization of undergraduate research participation.

Our models included demographic and pre-college experience measures that correlate with students' propensity to participate in undergraduate research experiences. We controlled for race (with White as the reference group), sex (female as the reference group), socioeconomic status measured as a composite of parental education and income, and whether either parent worked in a STEM-related career. Prior preparation variables measured students' high school

GPA, composite SAT scores (with ACT-equivalent scores computed), and the number of years students spent studying math, physical science, and biological science in high school. Our models predicting research participation also included measures of students' degree aspirations (with bachelor's degree as the reference group), career aspiration to work as a research scientist (versus any other career), and a lifelong goal to be well off financially. In matching students, we also accounted for academic and social self-confidence, pre-college research experiences, and students' self-reported STEM identity (Chang et al., 2011) upon college entry. Finally, we accounted for the discipline of students' bachelor's degree (with biological sciences as the reference group). Table 1 lists all of the individual-level variables in the model as well as their means, standard deviations, and ranges. Institution-level variables included control, size, selectivity, Carnegie classification, and whether the institution was a minority-serving institution.

Analyses

To account for possible self-selection bias inherent in our measures of undergraduate research experiences, we proceeded in several steps. First, we used logistic regression models to create a set of propensity scores associated with participating in undergraduate research (one propensity score for each of the three derivations of undergraduate research participation). Given that we did not have the ability to randomly assign students to undergraduate research participation, our quasi-experimental approach, designed to statistically adjust the sample to make the pre-college characteristics of research participants and non-participants more similar, represents the next best option (Guo & Fraser, 2010). This statistical adjustment allowed us to more accurately assess the effect of research participation on enrollment in STEM graduate or professional programs, as the pre-treatment characteristics of participants and non-participants begin to approach what we would expect from a random assignment (Schneider et al., 2007).

Because of the dichotomous nature of our ultimate outcome variable, we relied on the reweighting technique described by Guo and Fraser (2010) and Nichols (2008) and applied these weights in our HGLM analyses. We ran these models for all students and for a sample that contained only URM students (N=1,474). Running our final models in HGLM allowed us to account for the clustered nature of the data and determine whether institutional characteristics significantly moderated the effect of undergraduate research participation on enrollment in STEM graduate and professional programs (Raudenbush & Bryk, 2002).

Limitations

Because we relied on analysis of secondary data, we were limited by the variables and their definitions on the surveys. Additionally, the measure of enrollment in STEM graduate or professional programs occurred just seven years after college entry; thus, more respondents in our sample may move into these programs in the years to come. Finally, this study does not establish direct causal effects of research participation on enrollment in STEM graduate and professional programs, but our analytic approach attempts to address much of the selection bias associated with choosing to participate in undergraduate research.

Results

Table 1 presents descriptive statistics for the full sample. Just over one-third of the sample (35%) had enrolled in a STEM graduate or professional program by the summer of 2011. One in five respondents had participated in a structured undergraduate research program, and 45% of respondents reported having conducted research with faculty during their undergraduate years. Nearly half of the sample (48%) reported having participated in undergraduate research or conducting research with faculty.

About 10% of the sample identified as Latino, and 8% identified as Black. Roughly 3% of the sample was Native American, and 14% identified as Asian American. More than half (56%) of the sample was composed of women, and more than one-third (35%) of participants had at least one parents who worked in a STEM-related career.

A plurality of the sample (39%) graduated with a bachelor's degree in the biological sciences. The next most popular undergraduate major was engineering (27%) followed by the health sciences (13%). About one in 10 participants had graduated with a degree in the physical sciences, and 5% and 6% had completed a bachelor's degree in mathematics/statistics and computer science, respectively.

Table 2 presents the results from the logistic regressions used to create propensity scores for each of the three derivations of the undergraduate research variable for the full sample. Latino, Black, and Native American students were significantly more likely to have participated in a structured undergraduate research program compared to their White counterparts. Students with higher standardized test scores tended to be more likely to report having participated in a structured undergraduate research program, and pre-college research experiences significantly correlated with increased probabilities of conducting undergraduate research through a structured program. Students who earned a bachelor's degree in the physical sciences were significantly more likely to conduct research under the auspices of a structured program compared to their peers in the biological sciences; however, students who earned degrees in engineering, the health sciences, and computer science had a significantly reduced likelihood relative to their biological science counterparts of conducting undergraduate research through a structured program.

Asian American and Pacific Islander students were significantly more likely than their White peers to have conducted research with faculty. Prior academic achievement and pre-

college research experiences significantly and positively correlated with students' likelihood to participate in research activities as undergraduates. Similar to the model predicting participation in a structured undergraduate research program, we found that physical science majors were significantly more likely than their peers who majored in the biological sciences to report having conducted research with faculty; however, biological science students had significantly higher probabilities of conducting research with faculty compared to their counterparts in engineering, the health sciences, mathematics and statistics, and computer science.

Table 3 shows the results from the propensity-score-weighted and unadjusted (unweighted) HGLM analyses for the full sample and for the URM-only sample. Accounting for endogeneity in the data substantially reduced the magnitude of the relationship between research participation and enrollment in STEM graduate and professional programs. Structured undergraduate research program participants were roughly 9 percentage points more likely to enroll in STEM graduate and professional programs compared to non-participants. The effect of having conducted research with faculty is even stronger, as those who conducted research with faculty were 14 percentage points more likely to enroll in STEM graduate and professional programs compared to their peers who did not conduct research with faculty. Students with any research experience had a 14-point advantage in their probability of enrolling in STEM graduate/professional programs compared to those without any research experience.

The effects for URM students were even stronger. URM students in structured undergraduate research programs were 15 percentage points more likely to enroll in STEM graduate/professional programs. Conducting research with faculty predicted a 14-point increase in URM students' probability of enrolling in STEM graduate/professional programs, and URM students who had any research experience as undergraduates enjoyed a 17-point advantage in

their probability to enroll in STEM graduate/professional programs compared to their URM peers who did not have an undergraduate research experience.

Our tests for between-institution variance in the effect of undergraduate research on enrollment in STEM graduate and professional programs found that this effect remained stable across campuses. Results in Table 4 show that respondents who attended private undergraduate campuses were significantly more likely to enroll in a STEM graduate or professional program. Respondents who attended larger undergraduate colleges and universities tended to enroll in STEM graduate or professional programs at higher rates than their peers from smaller campuses. Enrolling in a more selective undergraduate institution did not significantly correlate with a higher probability of enrolling in a STEM graduate or professional program.

Discussion

Our findings support previous research affirming the positive benefits of undergraduate research participation (Bauer & Bennett, 2003; Carter et al., 2009; Eagan et al., 2013; Hathaway et al., 2002; Laursen et al., 2010; Ward et al., 2003). Even after accounting for possible selection bias associated with undergraduate research, we found that research participation significantly improves STEM bachelor's degree recipients' probability of enrolling in STEM graduate and professional programs – for all STEM degree holders and for URM STEM degree holders specifically. Our findings are slightly more conservative than those found in previous research that relied on descriptive statistics. We found that research participation increased respondents' probability of STEM graduate/professional program enrollment by roughly 9 to 14 percentage points whereas previous studies had estimated a 17- to 21-point gap (Bauer & Bennett, 2003; Hathaway et al., 2002), and we found that the effects for URM students were stronger than those found in the more general model. Our unadjusted model, shown in Table 3, is more in line with

the 17- to 21-point gap identified by previous research (Bauer & Bennett, 2003; Hathaway, 2002). The reduction in "effect" of undergraduate research after matching students to their peers who had similar motivations, abilities, and characteristics was in the neighborhood of six to eight percentage points.

The results suggest that it may not matter how students engage in undergraduate research experiences – either through structured programs or with faculty directly. This is not to say that formal structured programs are not important; they provide spaces for URM students in particular to connect with other URM students interested in science (Hurtado, Cabrera, Lin, Arellano, & Espinosa, 2009; Hurtado, Eagan, Tran, Newman, Chang, & Velasco, 2011) and can serve as a community of practice (Lave, 1991; Lave & Wenger, 1993; Wenger, 1998, 2000). In the spaces of structured research programs, participants not only engage in the shared purpose of research but also connect with peers and faculty in other ways, including professional development sessions focused on graduate school application, peer-to-peer mentoring, and structured mentoring with program directors. Additionally, structured programs are important for attracting URM STEM students into research, as our findings showed that Black, Latino, and Native American students were significantly more likely than their White peers to participate in a structured research program. We did not find significant differences between URM students and White students with regard to their odds of participating in research with faculty; thus, structured programs appear to be an effective strategy of increasing access to research experiences for URM STEM students.

One way for federal and private agencies seeking to expand the reach of undergraduate research experiences is to incentivize involving undergraduates on faculty research grants. Several federal agencies already provide such incentives where faculty can receive additional

funds for the promise of including undergraduates on their research team, and previous research has found that faculty who receive external research grants are significantly more likely to include undergraduates on their research teams (Eagan et al., 2011). Our findings indicate that direct involvement in research with faculty members has just as strong an effect on URMs' likelihood of pursuing STEM graduate work as that of structured research programs.

Future research needs to explore how the type of experiences students have when conducting research correlate with STEM persistence and STEM graduate and professional school enrollment. The models in this study merely accounted for having had research experience either through a structured program or directly with a faculty member. More needs to be learned about the kinds of activities occurring in the research labs and spaces with undergraduates and their faculty mentors. Additionally, studies need to examine whether the timing of research experiences matters. In this study, we had a measure representing whether, at any point in their undergraduate career, students had engaged in research. Given that research experiences socialize students toward thinking and acting like scientists and provide clarity for academic major and career aspirations, we might expect that earlier experiences (e.g., freshman or sophomore year) might have a stronger relationship with STEM persistence and subsequent enrollment in STEM graduate and professional programs than research experiences that occur later in a student's undergraduate career.

Our findings suggest that investments in undergraduate research by governmental agencies and private foundations are having the desired effect of increasing participants' likelihood of moving into STEM graduate and professional programs – particularly among URM students. Colleges and universities must continue to identify strategies to institutionalize undergraduate research experiences beyond the life of external grants. Doing so likely will have

lasting impacts not only on their ability to recruit and retain students in STEM degree programs but also facilitate these students' matriculation into STEM graduate and professional programs.

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Table 1

Descriptive Statistics for Variables Included in the Study

	Mean	Std. Dev.	Min	Max
Dependent Variable				
Enrolled in a STEM graduate or professional program	0.35	0.48	0.00	1.00
Key Independent Variables				
Conducted research with a faculty member	0.45	0.50	0.00	1.00
Participated in a structured undergraduate research program (e.g., MARC, MBRS)	0.20	0.40	0.00	1.00
Conducted undergraduate research (either with a faculty member or in a structured program)	0.48	0.50	0.00	1.00
Demographic Characteristics				
Race: Latino (White as reference group)	0.10	0.29	0.00	1.00
Race: Black (White as reference group)	0.08	0.27	0.00	1.00
Race: Native American (White as reference group)	0.03	0.17	0.00	1.00
Race: Asian American/Pacific Islander (White as reference group)	0.14	0.35	0.00	1.00
Race: Other (White as reference group)	0.02	0.12	0.00	1.00
Sex: Female (male as referenceg roup)	0.56	0.50	0.00	1.00
Socioeconomic status	20.67	5.50	1.09	38.55
Either parent has a STEM-related career	0.35	0.48	0.00	1.00
Prior Preparation				
High school GPA	7.15	1.12	2.00	9.46
Composite SAT scores (with ACT equivalent) (100)	12.47	1.70	4.60	16.00
Years of study in HS math	6.04	0.51	1.00	7.74
Years of study in HS physical sciences	4.11	1.25	0.58	7.73
Years of study in HS biological sciences	3.77	1.00	1.00	7.00
Pre-College Experiences				
Pre-college research experience	0.13	0.33	0.00	1.00
Academic self-concept (construct)	0.00	0.87	-4.60	1.80
Social self-concept (construct)	0.00	0.86	-2.66	2.49
2004 STEM identity (factor)	0.00	0.86	-2.20	2.23
Educational and Career Aspirations				
2004 Degree aspiration: Master's (bachelor's as reference group)	0.29	0.45	0.00	1.00
2004 Degree aspiration: M.D., D.D.O., D.D.S., etc. (bachelor's as reference group)	0.25	0.43	0.00	1.00
2004 Degree aspiration: Ph.D. or Ed.D. (bachelor's as reference group)	0.24	0.43	0.00	1.00
Career aspiration: Research scientist	0.08	0.28	0.00	1.00
2004 Goal: Be well off financially	2.99	0.86	1.00	4.00

Bachelor's Degree Majors				
Bachelor's degree major: Engineering (biological sciences as reference group)	0.27	0.44	0.00	1.00
Bachelor's degree major: Physical sciences (biological sciences as reference group)	0.10	0.29	0.00	1.00
Bachelor's degree major: Health professions (biological sciences as reference group)	0.13	0.33	0.00	1.00
Bachelor's degree major: Math/Statistics (biological sciences as reference group)	0.05	0.21	0.00	1.00
Bachelor's degree major: Computer science (biological sciences as reference group)	0.06	0.23	0.00	1.00

Table 2

Results from Logistic Regressions Predicting Research Participation

	Structured Program			Research with Faculty			Research via Program or Faculty		
	Log Odds	S.E.	Sig.	Log Odds	S.E.	Sig.	Coef.	Std. Err.	Sig.
Race: Latino	0.17	0.06	**	-0.06	0.06		-0.05	0.06	
Race: Black	0.29	0.07	***	0.00	0.06		0.04	0.06	
Race: Native American	0.24	0.10	*	0.08	0.09		0.15	0.09	
Race: Asian American/Pacific Islander	0.05	0.05		0.11	0.05	*	0.08	0.05	
Race: Other	0.09	0.14		0.17	0.13		0.23	0.13	
Sex: Female	0.01	0.04		-0.02	0.04		-0.01	0.04	
Socioeconomic status	0.00	0.00		0.00	0.00		0.00	0.00	
Either parent has a STEM-related career	0.09	0.04	*	0.01	0.03		0.05	0.03	
High school GPA	0.02	0.02		0.05	0.02	**	0.04	0.02	*
Composite SAT scores (with ACT equivalent) (100)	0.00	0.00	***	0.00	0.00	***	0.00	0.00	***
Years of study in HS math	0.02	0.04		0.08	0.03	*	0.07	0.03	*
Years of study in HS physical sciences	0.00	0.01		0.05	0.01	***	0.04	0.01	***
Years of study in HS biological sciences	0.03	0.02		0.02	0.02		0.03	0.02	
Pre-college research experience	0.28	0.05	***	0.25	0.05	***	0.28	0.05	***
Academic self-concept (construct)	0.06	0.03	*	0.02	0.02		0.02	0.02	
Social self-concept (construct)	-0.01	0.02		0.05	0.02	*	0.05	0.02	*
2004 Degree aspiration: Master's	0.08	0.05		0.02	0.05		0.00	0.04	
2004 Degree aspiration: M.D., D.D.O., D.D.S., etc.	0.15	0.06	*	0.19	0.05	***	0.19	0.05	***
2004 Degree aspiration: Ph.d. or Ed.D.	0.24	0.06	***	0.25	0.05	***	0.23	0.05	***
Career aspiration: Research scientist	0.16	0.06	**	0.22	0.06	***	0.20	0.06	***
2004 STEM identity (factor)	0.11	0.02	***	0.14	0.02	***	0.14	0.02	***
2004 Goal: Be well off financially	-0.06	0.02	*	-0.08	0.02	***	-0.07	0.02	***
Bachelor's degree major: Engineering	-0.12	0.05	*	-0.38	0.05	***	-0.34	0.05	***
Bachelor's degree major: Physical sciences	0.33	0.06	***	0.30	0.06	***	0.33	0.06	***
Bachelor's degree major: Health professions	-0.41	0.07	***	-0.90	0.06	***	-0.78	0.06	***

Bachelor's degree major: Math/Statistics	-0.14	0.09		-0.84	0.08	***	-0.68	0.08	***
Bachelor's degree major: Computer science	-0.41	0.09	***	-0.54	0.08	***	-0.53	0.08	***
Constant	-3.15	0.41	***	-2.63	0.37	***	-2.68	0.36	***

Table 3

Results from Propensity-Score Matched HGLM Analyses Predicting Enrollment in Graduate/Professional STEM Programs

	Adjusted				Unadjusted			
	Log Odds	S.E.	Sig.	Delta-P	Log Odds	S.E.	Sig.	Delta-P
General Model - All Students								
Participation in a structured undergraduate research program	0.39	0.08	***	0.09	0.62	0.06	***	0.15
Conducted undergraduate research with faculty	0.63	0.06	***	0.14	0.95	0.05	***	0.22
Conducted undergraduate research with faculty and/or in a structured program	0.61	0.06	***	0.14	0.91	0.05	***	0.20
URM-Only Model								
Participation in a structured undergraduate research program	0.68	0.03	***	0.15	0.73	0.02	***	0.18
Conducted undergraduate research with faculty	0.64	0.03	***	0.14	0.91	0.02	***	0.20
Conducted undergraduate research with faculty and/or in a structured program	0.71	0.03	***	0.17	0.9	0.02	***	0.20

Table 4

Coefficients of Institutional Variables Predicting Enrollment in Graduate/Professional STEM Programs

	Log Odds	S.E.	Sig.	Delta-P
Level-1 Model				
Participation in a structured undergraduate research program	0.39	0.08	***	0.09
Level-2 Model				
Control: Private	0.51	0.14	***	0.11
Undergraduate full-time equivalent enrollment	0.19	0.08	*	0.04
Selectivity (100)	0.07	0.05		
Liberal arts	0.50	0.17	**	0.12
Masters comprehensive	0.01	0.13		
HBCU	-0.48	0.28		
HSI	-0.03	0.28		
Emerging HSI	0.20	0.25		