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The Impact of Graduate-Level Structured Research Programs on Degree Attainment and Doctoral Study

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Abstract

The study investigated the impact of the Minority Opportunities in Research (MORE) programs on science graduate students from traditionally underrepresented backgrounds at a southern California comprehensive university. A propensity score matching design was used with ten years of data on participants and non-participants. 145 MORE students were matched with a group of non-MORE graduate students enrolled over the same time period on a number of relevant covariates. Students in the MORE group outperformed those in the comparison group in multiple areas: greater numbers of the MORE students completed their degrees; more of them were accepted to doctoral programs; they had higher GPAs at graduation; and took less time to earn degrees. Furthermore, binary logistic regression models used to predict graduation and entrance to science PhD programs found participation in the MORE programs to be a strong predictor of both outcomes. Results are discussed in light of the propensity score matching, as well as in the context of graduate student research.

Keywords: structured research programs, underrepresented minorities, graduate students, propensity score matching

1. Introduction

In 2005 the US Congress tasked the National Academies to provide a report detailing the current state of the US scientific enterprise and recommend to the federal government actions necessary to maintaining the global preeminence of US science and engineering (National Academies Press, 2007).

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The resulting publication contained four such recommendations among which was a call for an increase in the number of students who graduate with undergraduate degrees in STEM (science, technology, engineering, and mathematics) and pursue graduate education in those fields. Students who belong to minority groups play an essential role in realizing that increase; indeed an increasing number of future scientists will have to come from these groups in order to maintain the nation's scientific output, given their growing representation in the US population. Students of minority groups that are currently underrepresented in science and engineering (American Indians and Alaska Natives, Hispanics, and African Americans) are particularly critical, both due to being some of the fastest growing segments of the population, and because as the National Academies' report rightly notes, "if some groups are underrepresented in science and engineering in our society, we are not attracting as many of the most talented people to an important segment of our knowledge economy" (National Academies Press, 2007: 167).

Observations such as these regarding the underrepresentation of minority groups in STEM fields are far from new. Nonetheless, widespread acknowledgment of the situation has not as of yet led to any great improvement. The ratio of Hispanic, African and Native American science doctorate earners to their total representation in the US population has stayed essentially flat between 2000 and 2008 (National Science Foundation, 2011). While accounting for approximately 28% of the US population, these students only accounted for 18% of the population of science graduate students enrolled at US universities in 2008, and received just 12% of the doctorates awarded in science fields. This representation in the NSF data stands in contrast to the productivity of White and Asian students in science doctoral programs; these students both obtain a higher proportion of doctoral degrees in the sciences than their representation in the US population (Figure 1).

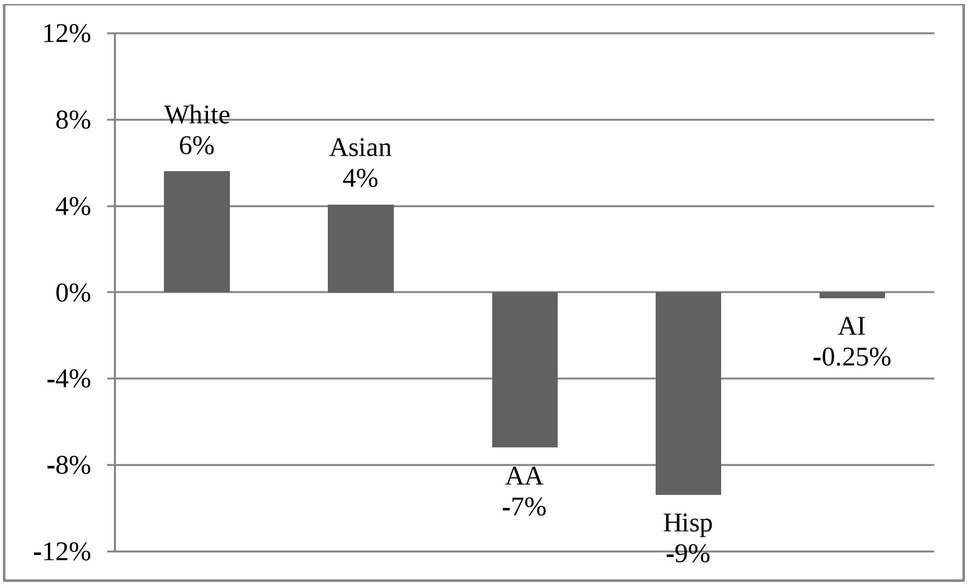

Figure 1: *Difference in percentage of earned science doctorates by race/ethnicity vs. representation in US population*

The ongoing underrepresentation of these students in the science degree programs has been explained by a number of factors, including inadequate preparation for science and math degree programs in high schools (Brown & Campbell, 2009; Swail, 2003; Schneider, 2000; Astin, 1993), the lack of financial assistance in paying for college (Fenske, Porter, & DuBrock, 2000; Astin, 1992), and an unwelcoming campus climate and feelings of social isolation reported by significant numbers of both minority undergraduates and graduate students (Bonous-Hammarth, 2000, 2006; Wilson, 2000; Seymour & Hewitt, 1997; Tobias& Lin, 1991).

Concurrent with examinations of why students, in particular those from backgrounds traditionally underrepresented in science and math degree programs, fail to persist in the sciences have been the development of programs and strategies meant to address the barriers to success in science degree programs and increase the number of students earning doctorates in these fields. Such programs generally provide opportunities for students to participate in structured research opportunities on campus, financial assistance so as to preclude them from having to seek off-campus part-time work (or dropping out entirely to work full time), and they are given access to resources such as tutoring or supplemental instruction to account for deficiencies in their academic preparation (Slovacek, Tucker, & Whittinghill, 2008).

2. The MORE Programs at an Urban Public University

The current study examines a structured research program, the National Institutes of Health (NIH) Minority Opportunities in Research (MORE) program at a major urban public university in Los Angeles, and the impact it has had on students pursuing terminal Master's degrees over the past ten years. This university was selected due to the high concentration of underrepresented students enrolled, as well as having several long-running structured research programs targeting students from backgrounds traditionally underrepresented in the sciences.

The MORE programs (which included the Research Initiative for Scientific Enhancement (RISE), the Post-baccalaureate Research Education Program (PREP) and the Bridges to the PhD) offered paid research positions in on campus labs under the guidance of faculty mentors, opportunities to conduct research at doctoral granting institutions in the greater Los Angeles metropolitan area, seminars on current topics in biomedical research (frequently delivered by current or former MORE-supported students), and guidance in preparing applications for PhD programs. The research presented in this study is part of the culmination of a six-year research project which sought to assess the efficacy of the MORE programs in supporting student persistence towards earning degrees in biomedical science degree programs, as well as entrance into doctoral study.

3. Previous Research

The rationale behind involving students in structured research experiences is that they aid students in acculturating into the scientific community, encourage self-efficacy and identification as a scientist, improve understanding of scientific research concepts and practices, and encourage them towards pursuing careers in the sciences. Research on subsequent impacts supports this rationale. Hunter, Laursen, and Seymour (2007) and Seymour et al (2004) report research experiences as promoting students' perceptions of themselves as scientists, a finding corroborated by faculty who oversaw the students' research. Such experiences may also affect students' future career goals and determination to pursue advanced degrees (Lopatto, 2004). Kardash (2000) found conducting research led to increased student knowledge of the scientific process.

In addition to the research experience, programs such as MORE also provide academic support for students in the form of tutoring, academic advisement, and supplemental instruction courses.

Students with inadequate preparation during their high school careers have a higher rate of leaving the university than those who entered more fully prepared for the academic rigor in their coursework (Tinto, 1990).As such these programs seek to make up for deficiencies in students' high school coursework and support them in gateway courses necessary for success in their degree programs (Pascarella & Terenzini, 2005; Barlow & Villarejo, 2004). The benefits of supplemental instruction as implemented in the MORE programs are discussed in Peterfreund et al (2008) and Rath et al (2007), both of which examine the impact of the supplemental instruction on minority student performance at San Francisco State University. Over a six year period, participants were found to be more likely to pass the corresponding courses than those who did not receive supplemental instruction (Rath et al, 2007). Students who partook in supplemental instruction also demonstrated better progression through subsequent courses (Peterfreund et al 2008). The impact of this intervention was particularly pronounced for students who were members of minority groups.

The financial assistance provided to students is designed to ameliorate the financial difficulties many minority students face in higher education. Hurtado et al (2007) found students from underrepresented groups were frequently impacted by financial and family pressures, and to be more concerned with the ability to finance college. This aid also frees them from having to pursue part-time work off-campus, which has been found to have a negative impact on persistence (Gardner & Broadus, 1990; Astin, 1982). While African American, Hispanic, and American Indian students are more likely to receive aid than their Caucasian or Asian peers, the aid they receive is on average less (National Science Foundation, 2003), and underrepresented minority students have been disproportionally affected by diminishing number of need-based grants, which have generally been replaced with either loans or grants based on merit (Swail, 2003).

Though programs such as MORE have been made available to all types of students, there is reason to believe that they may be particularly important for students belonging to groups traditionally underrepresented in the sciences. Studies such as Barlow and Villarejo (2004) and Maton, Hrawboski, and Schmitt (2000) both document the success of research programs in promoting success at the undergraduate level among members of underrepresented groups.

Indeed, by fostering a sense of community (Hurtado et al 2009) structured research programs may be well situated to counteract the feelings of isolation that inhibit members of underrepresented groups from persisting in the sciences. Currently lacking in the literature are studies which employ more rigorous methods in the investigation of programs such as MORE and their impact on graduate students traditionally underrepresented in the sciences.

Previous research has generally been limited by the voluntary nature of the programs, which has meant that comparisons to non-participants are confounded by selection bias. The present study addresses this gap by comparing outcomes from MORE-supported graduate students to a group of non-supported similar students created using propensity score matching. Matching was conducted one-to-one (each MORE-supported student was matched with one non-MORE supported student) using a propensity score that represents the likelihood of a particular student participating in the MORE program based on a number of observed covariates.

Furthermore, to date, the majority of research into the effectiveness of structured research programs has examined its impact on undergraduate populations; little work has been done which investigates their role in supporting graduate students, specifically those students enrolled in Master's programs. This may be due to many such programs existing at doctoral-granting institutions, which focus on preparing undergraduates primarily to enter PhD study upon graduation. Nonetheless, Master's programs permit students who may not be completely prepared for PhD study opportunities to improve their research skills and understanding of their chosen fields, which in turn could make them more attractive candidates for doctoral programs. This last assertion is contentious, and may vary by field. Bonifazi, Crespi, and Rieker (1997) reported that, among various psychology doctoral programs, attitudes were mixed regarding the value of a prior Master's degree in doctoral admissions. Research in doctoral program completion (Most, 2008) has shown a positive effect for those students who had a prior Master's degree, though they constituted a minority of the doctoral students in the analysis. This effect was particularly strong in biochemistry, where the 9-year completion rate was 63% for students possessing a Master's, and 45% for those who did not (Most, 2008). There is a need for more research into the role structured research programs can play in Master of Science programs, in particular what advantages it can provide students beyond those gained through the research they might already conduct as graduate students.

The present study seeks to answer the following questions:

1. When compared to a propensity score-matched comparison group, do MORE-supported graduate students earn science master degrees at higher rates?
2. Upon graduation, do MORE-supported graduate students report higher grade point averages than the comparison group?
3. Do MORE-supported graduate students report a shorter time-to-degree than the comparison group?
4. Are MORE-supported students more likely to enter PhD programs in the biomedical sciences than the comparison group?

The first three questions relate to the extent to which the MORE program supports students academically and encourages persistence towards graduation. The last investigates the impact of the program on students' progression towards becoming practicing researchers in biomedical sciences careers.

4. Methodology

4.1 Design

The study employed a causal-comparative design utilizing propensity score matching to reduce the selection bias inherent in MORE program participation. The population of all MORE supported graduate students at the university from 2000 through Spring2010 was compared with a group of non-MORE graduate students enrolled over the same time period and matched with the MORE supported students on a number of relevant covariates. Comparisons were made between the two groups with respect to graduation, grade point average, time to degree completion, and acceptance to PhD programs in the sciences. The average treatment effect of being a MORE programs participant was also estimated using binary logistic regression.

4.2 Subjects

Data used in this study was drawn from the student population at an urban public university, which is a Title V Hispanic-serving institution situated in East Los Angeles.

The makeup of the surrounding community is reflected in that of the campus; in addition to being majority Hispanic, 73% of incoming freshman come from families making less than $24,000 per year, and 80% are awarded some form of financial aid. Underrepresented students make up approximately half of graduate students in the sciences, and account for two-fifths of the science master degrees awarded. The study initially collected data from university records on the population of all graduate students enrolled in the College of Natural and Social Sciences between the Fall quarter of 2000 and Spring of2010and funded by at least one of the MORE programs at the university over that same time period. 161 graduate students met these criteria and were included in the analysis.

These students were selected for support by the MORE programs following a series of interviews with program leadership, review of academic records, and an application packet which includes a curriculum vita, letters of recommendation and a personal statement. Students supported by MORE must be pursuing a graduate degree in one of the following four subjects: biology, mathematics, chemistry or psychology. Those who change programs to one not of the four listed lose all support.

To approximate the random assignment of subjects found in an experimental design, a comparison group of non-MORE supported graduate students was created using propensity score matching to allow for a more accurate comparison of MORE and non-MORE student outcomes. Members of the comparison group were drawn from the population of 1,625 graduate students not supported by MORE and enrolled in one of the four majors supported by MORE between 2000 and 2010 and matched with a member of the MORE-supported group. The propensity score matching procedure is discussed in detail below.

4.3 Data Collection

The majority of information on students, including academic plans, degree programs, grade point averages, and matriculation and graduation, was gathered through university institutional records. Data from the MORE program offices at the university served as a secondary source for data on graduation for MORE supported students, as well as information on post-graduation plans (i.e. graduate study and completion of advanced degrees).

The National Student Clearinghouse (www.studentclearinghouse.org) furnished data on enrollment in and graduation from institutes of higher education for all students enrolled in the College of Natural and Social Sciences between 2000 and 2010, including those students supported by MORE. This information was further corroborated and updated through Internet searchers via Google, LinkedIn, numerous university websites, and online dissertation and thesis databases such as WorldCat and Dissertation Abstracts. Appendix A details each data source, its scope, and the type of information provided.

4.4 Propensity Score Matching

Applicants to the MORE programs must submit an application packet containing transcripts and letters of recommendation, as well as submit to an interview process intended to gauge their commitment to science and their motivation to obtain a doctoral degree in the sciences.

To control the bias introduced by the non-random process by which students were selected to be in the MORE group, the study employed propensity score matching to generate a matched comparison group from the population of non-MORE participants in the College of Natural and Social Sciences.

First introduced by Rubin and Rosenbaum (1983), the propensity score represents the predicted probability that a given case would be selected for treatment based on a set of observed predictors. Propensity scores were calculated via binary logistic regression for all students supported by MORE, as well as all non-MORE students in the population of graduate students in the College of Natural and Social Sciences who had been enrolled in one of the MORE-supported degree programs. Variables to be included in the logistic regression model used to generate the propensity score were selected provided they met at least one of the following criteria: the variable was related to selection as a MORE participant; the variable exhibited statistically significant differences between MORE and non-MORE students; the variable was believed to be related to any of the outcomes based on the previous research. Variables used for matching were student's choice of major, ethnicity, gender, age, and the type of institution at which they earned their bachelor's degree (public or private, as well as whether the institution was in California or not).

Prior to matching, the extent of the differences between supported and non-supported students depended upon the variable (Table 1, below); there was roughly the same proportion of men and women in each group, and mean ages and matriculation years were also quite similar. On the other hand, MORE-supported students pursued degrees in biology and chemistry more frequently than their non-supported counterparts, and the proportion of students belonging to ethnic groups traditionally underrepresented in the sciences was higher among MORE-supported students. Students who received support from the MORE programs were also more likely to have earned a bachelor's from other local public universities.

Variable	Non-MORE students N = 1625		MORE students N = 161	
Institute of Origin	The university: 31%	CA Private: 8%	The university: 40%	CA Private: 6%
	Other CSU: 14%	Out of State: 11%	Other CSU: 10%	Out of State: 9%
	UC: 25%	Foreign: 11%	UC: 32%	Foreign: 3%
Age	x= 29, sd = 8		x= 27, sd = 5	
Matriculation Year	$\bar{x}$= 2003, sd = 4		$\bar{x}$= 2003, sd = 3	
Major	Bio: 22%	Physics: 4%	Bio: 47%	Physics: 0.6%
	Chem: 9%	Psy: 44%	Chem: 29%	Psy: 22%
	Math: 21%		Math: 2%	
Gender	M: 42%	F: 58%	M: 45%	F:55%
Ethnicity	Amer Ind.: 0.4%	Pac. Islander: 3%	Amer Ind.: 1%	Pac. Islander: 5%
	Afr. Amer.: 9%	White: 11%	Afr. Amer.: 14%	White: 4%
	Asian: 12%	Unknown: 12%	Asian: 2.5%	Unknown: 6%
	Hisp.: 52%		Hisp.: 67%	

Table 1: Matching Variables, Pre-Matching

The resulting propensity score calculated by the regression represented for each student in the database the probability of having been selected as a MORE participant based on the above covariates.

Matching was accomplished using the nearest-neighbor procedure (having first sorted the cases randomly) with a caliper value of 0.25 standard deviations, approximately 0.037 on a scale which runs from 0 to 1. Matches were one-one without replacement; for each MORE student, the closest non-MORE student with a propensity score within 0.25σ was selected, after which both cases were removed from the list for matching. The resultant matched dataset contained 145 of the MORE students matched with 145 non-MORE students.

Attempts were made to match more of the MORE students by widening the caliper, however increasing the caliper to 0.5σ did not result in a much larger number of matches; it was decided that the loss of 16 students (to 145 from the original 161 MORE-supported students) was acceptable in return for a better matched comparison sample.

Prior to matching large differences existed between the propensity scores of MORE students and non-MORE students. Graduate students supported by MORE had on average a propensity score of 0.33 with a standard deviation of 0.22. Those students who did not participate in the MORE programs had a mean propensity score of 0.066 and a standard deviation of 0.11. Post-matching, mean propensity scores were identical to within two decimal places, and standard deviations were nearly the same as well. Table 2 displays descriptive statistics for the propensity scores for each of the two groups. Note that two of the majors, math and physics, are no longer represented in the matched dataset.

	N	Minimum	Maximum	Mean	Std. Dev.
Comparison group	145	0.01	0.76	0.30	0.20
MORE students	145	0.01	0.72	0.30	0.19

Table 2: Propensity Score Results by Group, Post-Matching

With respect to the specific variables used in the matching, Table 3 revisits the variables used in the logistic regression model after propensity score matching. The proportion of students within each major was approximately equal, as was that of each ethnicity. The similarities with respect to gender, age, and year of matriculation persisted post-matching, and the percentage of MORE-supported students from each type of institution of origin was within a few percentage points of those in the matched comparison group.

Compared to the population of non-MORE-supported students from which it was drawn, the matched comparison group signifies a large improvement with regards to comparability to the population of MORE students (Table 3); none of the observed differences was statistically significant at the $p < .05$ level.

Variable	Non-MORE students N = 145		MORE students N = 145	
Institute of Origin	The university: 42% Other CSU: 7% UC: 33%	CA Private: 4% Out of State: 9% Foreign: 4%	The university: 38% Other CSU: 10% UC: 32%	CA Private: 7% Out of State: 9% Foreign: 3%
Age	$\bar{x}$= 26, sd = 5		$\bar{x}$= 27, sd = 5	
Matriculation Year	$\bar{x}$= 2004, sd = 4		$\bar{x}$= 2004, sd = 3	
Major	Bio: 54% Chem: 21% Psy: 25%		Bio: 53% Chem: 22% Psy: 25%	
Gender	M: 42%	F: 58%	M: 45%	F:55%
Ethnicity	Amer Ind.: 1% Afr. Amer.: 12% Asian: 3% Hisp.: 67%	Pac. Islander: 4% White: 4% Unknown: 9%	Amer Ind.: 1% Afr. Amer.: 14% Asian: 3% Hisp.: 64%	Pac. Islander: 5% White: 4% Unknown: 7%

Table 3: Matching Variables, Post-Matching

4.5Analysis

Post-matching, comparisons were made with respect to the number of graduates from each degree program, mean GPA at graduation, mean time to degree, and the number of graduates who were accepted to a PhD program in the sciences. The effect size (Cohen's d) was used to calculate the size of the difference between each group with respect to mean GPA and time to degree.

The effect of MORE participation was estimated using two logistic regression models. The first examined the impact of MORE participation on graduation from the university with a Master's degree, while the second regressed MORE participation and other potential factors and covariates upon acceptance to a PhD program in the sciences.

5. Results

5.1 Comparison of Outcomes

5.1.1 Graduation.

Over the period of the study, 78(54%) of the 145MORE graduate students included in the study received a Master's degree in one of the four MORE-supported fields. Of the remaining67students, 23 were still enrolled as students and had not left the MORE programs at the time of this study, 23had either switched to a non-MORE supported major, transferred to a different institution, or dropped out of the university and 21 had entered a PhD program without having graduated from the university. Among the 145 students in the matched comparison group, 48 (33%) had earned a Master's degree between 2000 and 2010, with 25 still enrolled in courses and 70 who had either changed majors, transferred, or dropped out. One student had entered a PhD program prior to completing their Masters. Table 4 summarizes the degree status of students in each group.

	Graduates	Currently Enrolled	Dropped Out/Changed majors	Entered PhD w/o Masters	Total
MORE	78 (54%)	23 (16%)	23 (16%)	21 (15%)	145
Comparison	48 (33%)	25 (17%)	71 (49%)	1 (0.01%)	145

Table 4: Degree Status as of Spring 2010

The percentage of students who had completed their Master's degree was 21% higher among MORE students than among those in the non-MORE group. As a point of comparison, the graduation rate for the Master's students of the university within each of the four MORE-supported majors between 2000 and Spring 2010 averaged approximately 40%.

Table 5 below breaks down the number of graduates from each group by major. Results demonstrate that MORE students graduated more frequently in all MORE-supported fields except mathematics, in which only 3 students earned degrees.

	Biology	Chemistry	Mathematics	Psychology	Total
MORE	41	13	1	23	78
Comparison	25	10	2	11	48

Table 5: Number of graduates by major

5.1.2 Grade Point Average at Graduation.

For those students who received a Master's degree from the university during the time period of the study, the grade point average at graduation was available through institutional records. The average GPA at graduation for students supported by the MORE programs was 3.60, while for graduates in the matched comparison group that value was 3.52. These averages, along with standard deviations and the effect size (Cohen's d) for the difference between the two GPAs are given in Table 6.

	N	*Mean GPA at graduation*	*Standard Deviation*	*Effect Size*
MORE students	79	3.60	0.261	
Non-MORE students	48	3.52	0.252	0.31

Table 6: GPA at graduation

The minor difference in average GPA at graduation between the two groups is evident in the relatively small effect size, and observing only those students who have graduated restricts the analysis to those who performed well enough academically to earn a degree. As students are required to maintain a minimum GPA of 3.00 to stay in their degree program, the small standard deviations in average GPAs are to be expected.

5.1.3 Time to Degree Completion.

Differences existed between MORE and non-MORE students with respect to the mean number of years taken to graduate with a Master's degree (Table 7). MORE students on average received a Master's degree 2.66 years following matriculation, while students in the comparison group averaged 3.89 years or more than a year longer.

Cohen's d for the difference between these means was 0.69, a high effect size. As a point of further comparison, the average time to degree for all graduate students who earned a degree in one of the three included majors between 2000 and 2010 was 3.77 years.

	N	*Mean Time to degree*	*Standard Deviation*	*Effect Size*
MORE students	79	2.75	1.18	
Non-MORE students	48	3.93	2.11	0.69

Table 7: Time to degree

Mean time to degrees varied according to the degree program, and illustrates that the differences in mean time to degree between the two groups is largely a consequence of MORE-supported biology and psychology students graduating much sooner than their unsupported counterparts. MORE-supported psychology and biology students had on average the shortest times to degree, whereas psychology and biology students who received no support from MORE had the longest overall. Average time to degree among chemistry students was approximately equal, though chemistry students only represented 23 of all students included in their analyses. Mean times to degree are provided for each degree program below in Figure 2; mathematics is not included due to only three students having earned a degree in the subject.

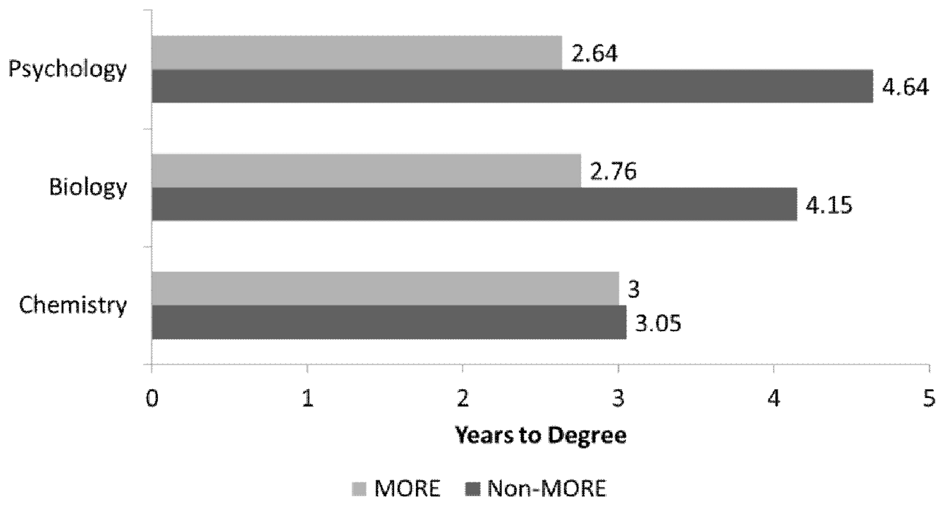

Figure 2: Mean time to degree by field

5.1.4 PhD study.

A total of 62 MORE-supported graduate students had been accepted to doctoral programs in the sciences at the time the study's completion.

Of these, 41 also earned a Master's degree from the university, with the remaining 21 having entered their doctoral program without completing their Master's. Barring those students who were still pursuing their Master's degrees at the time of data collection, the number of students accepted to doctoral programs represents 51% of MORE-supported graduate students. Among those students in the matched comparison group, only 7 had been accepted to a doctoral program, 6 of which also earned a Master's degree from the university. Nearly <u>nine</u> times as many MORE-supported students entered PhD study as those in the comparison group. Figure 3 displays the number of students accepted to PhD degree programs for both the MORE and comparison groups.

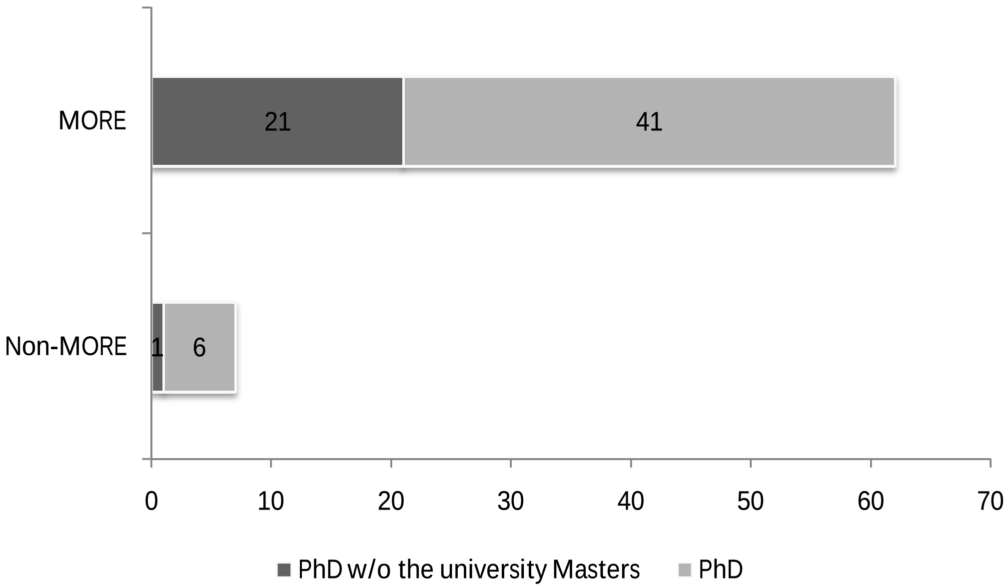

Figure 3: Acceptance to Science Doctoral Programs

Generally those students, MORE and non-MORE, who entered PhD programs without having first graduated had completed all the coursework for their degree program but failed to submit their theses.

5.2 Logistic Regression Models

The effect of being a MORE participant was estimated using logistic regression on two outcomes: completion of a Masters' degree in one of the MORE supported majors, and acceptance into a PhD program in the sciences. Initially the two outcomes were regressed solely on participation in the MORE program; variables on demographics, choice of major and first level interactions were added in subsequent models. Model selection was accomplished based on substantive interpretation of the models and the Akaike Information Criterion (AIK). Summaries of all the models tested are given in the appendices, with the final models discussed below.

Graduation from the university with a Master's degree was regressed initially on MORE participation, subsequent models added matriculation year, student demographic variables, choice of major, and first order interactions with MORE participation. Summaries of these models are in Appendix B. The final model (Table 8) included main effects for MORE participation, matriculation year, student demographics (age, gender, member of underrepresented group), having attended the same university as an undergraduate, major (chemistry or psychology, with biology as the reference group), and the interaction between MORE participation and attendance at the same university as an undergraduate.

Variable	β	S.E.	Odds ratio	95% Confidence Interval
MORE Participation	1.7***	0.35	5.47	[2.82 – 11.02]
Matriculation Year	-0.11*	0.05	0.89	[0.81 – 0.99]
Gender: Female	0.92**	0.31	2.50	[1.36 – 4.60]
Age	-0.24	0.43	1.02	[0.95 – 1.09]
Member of Underrepresented group	0.02	0.03	0.78	[0.33 – 1.81]
Attended the university as an undergraduate	0.93	0.16	2.53	[0.97 – 6.77]
Chemistry major	0.30	0.35	0.92	[0.42 – 2.02]
Psychology major	-0.08	0.40	1.34	[0.68 – 2.69]
MORE Participation x Univ. Undergrad	-2.16***	0.65	0.12	[0.03 – 0.41]

*p<0.05,**p<0.01,***p<0.001

Table8: Logistic Regression Model: Completion of Master'sDegree

The beta weights (β) given in the table above represent how a change in the corresponding variable is associated with a change in the probability of the outcome, in this case completion of a Master's degree. A positive beta weight means that as the variable increase, so does the likelihood of the outcome. A negative beta weight then means that an increase in that variable results in a decrease in the likelihood of the outcome. Thus MORE participation (which is coded as "0" for non-participants and "1" for participants) is positively associated with the likelihood of graduation with a Master's degree, whereas matriculation year had a negative beta weight and therefore an increase in matriculation year (that is to say, having entered the university more recently) was associated with an expected decrease in the likelihood of earning a Master's degree. Of the nine variables in the model, only four (MORE participation, gender, matriculation year, and the interaction between MORE participation and having attended the university as an undergraduate) were statistically significant predictors of earning a Master's degree.

Though indicative of the relationship between each independent variable and the likelihood of the dependent variable, to better understand the magnitude of the change in likelihood of the outcome, one must examine the odds ratios given in the third column of Table 8. The odds ratios, as the name implies, are the ratio of the odds of the outcome for one set of cases to the odds for a second one. For example, the odds ratio for MORE participation could be calculated as the odds of a MORE participant earning a degree divided by the odds of a non-participant earning one. The odds ratios given in the table above are adjusted for the presence of the other variables in a manner conceptually similar to partial correlations in multiple linear regression. Returning to the results of Model 1, the variable encoding participation in MORE has an adjusted odds ratio of 5.47, that MORE-supported students (for whom the variable was equal to "1") were 5.47 more likely to earn a degree than those who were not supported (for whom the variable equaled "0"), keeping all other variables constant. The 95% confidence interval for the adjusted odds ratio is an indication of the amount of uncertainty in that estimate.

Examining the odds ratios in Table 8, participation in the MORE programs was the largest predictor of completion of a Master's degree. Females were also found to be more likely to graduate than males, and the interaction between having attended the institution as an undergraduate and participation in MORE was a significant negative predictor. That is, the effect of MORE participation on earning a Master's degree differed according to whether or not a student had attended the institution as an undergraduate.

Among the matched comparison group there was only a small difference between the graduation rates between those who had previously attended the university and those who had not, however the difference was much larger among MORE students, in favor of those who had not attended the university as undergraduates. Figure 4 illustrates the interaction.

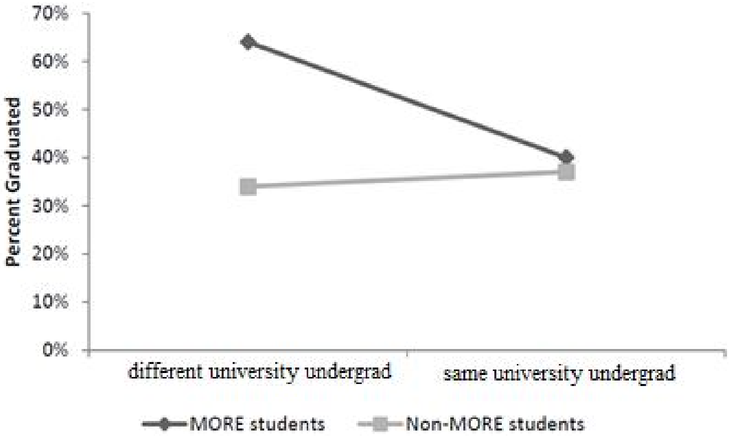

Figure 4: Percentage of graduates by MORE participation and undergraduate institution

Turning to acceptance into PhD programs the final model (Table 9) included main effects for MORE participation and GPA at graduation, as well as matriculation year which, will not a statistically significant predictor was included to account for multiple cohort nature of the data. Student demographics, majors, and interactions were attempted but did not improve model fit. Details of all attempted models are given in Appendix C.

Variable	β	S.E.	Odds ratio	95% Confidence Interval
MORE Participation	1.91***	0.52	6.75	[2.44 – 18.71]
GPA at graduation (standardized)	1.04***	0.26	2.83	[1.67 – 4.71]
Matriculation year	0.09	0.07	1.09	[0.95 – 1.25]

*p<0.05,**p<0.01,***p<0.001

Table 9: Logistic Regression Model 2: Acceptance into PhD program

The final regression model estimated MORE participants as being more than 6 times more likely to be to doctoral programs than students in the matched comparison group, and each standard deviation above the mean GPA at graduation increased the likelihood of acceptance to a PhD program by 2.7. Given that average GPA at graduation was very high (MORE group: $\bar{x}$=3.6, sd = 0.26; comparison group$\bar{x}$ = 3.5, sd = 0.25) for both groups, the strong predictive power of the variable demonstrates that relatively small changes in students' grades can potentially have a significant impact on the likelihood of earning acceptance into a doctoral program.

6. Discussion

Returning to the first of the research questions posed, MORE students outperformed their matched counterparts with respect to the number of degrees earned over the time period of the study. Of the 145 MORE-supported students, 78 earned degrees in biology, chemistry, or psychology, compared with 48 degree earners among the comparison group. Results were consistent across degree program; MORE participants graduated at higher rates across all three majors supported by the MORE programs. Results from the logistic regression model found that, after controlling for a number of other covariates, MORE participation was the strongest predictor of completing a Master's degree.

As to the second research question, GPAat graduation, the observed difference is practically speaking not terribly significant; as it pertains to PhD admissions a 3.60 GPA (the average among MORE students) is not much more impressive than a 3.52 (the average among the comparison group). The small differences observed are likely a consequence of the restriction of range, as those students who did not maintain high GPAs were unlikely to have persisted to graduation. Students' GPA at entry was not included in the propensity score matching, due to excessive missing data. However, examining those students for whom data was available (approximately 60% for both groups) showed no differences in mean GPA at the point of matriculation into the university as graduate students (both had an average of $\bar{x}$ = 3.15, sd = 0.45).Those MORE students who persisted to graduation earned a slightly higher GPA than those comparison group students, despite likely having entered at approximately the same level.

Average time to degree (research question 3) was significantly shorter and less varied among MORE students than among the comparison group. This result was consistent across degree program, with MORE-supported biology students graduating sooner than biology students in the comparison group, and likewise for chemistry and psychology students.

The last research question asked whether or not MORE-supported students are more likely to enter doctoral programs in the biomedical sciences than those students in the comparison group. The raw number of graduates who entered PhD programs was far greater among MORE participants than among those in the comparison group, with a ratio of MORE to non-MORE students entering PhD programs of approximately 9:1.The regression model identified MORE participation as the strongest predictor of entrance into a PhD program, even controlling for a student's GPA at graduation.

This strong association between program participation and PhD entrance has been seen in related research of program similar to MORE. Notably, a largely identical study (Slovacek, et al, 2012) was conducted comparing undergraduates supported by the MORE programs with a matched comparison group, and found similar effects with respect to program participation and advancement to PhD programs. Likewise, Pender et al (2010), Carter, Mandell, and Maton (2009) and Barlow and Villarejo (2004) all found positive relationships between participation in various types of structured research programs and degree attainment and entrance into PhD programs. However these studies involved undergraduates, the vast majority of whom are not engaged in scientific research.

Thus previous research has typically started from the assumption that it is the research opportunities (or lack thereof) that primarily distinguishes participants from non-participants, and consequently observed differences between those two groups are mainly attributed to this distinction. Graduate students, particularly those in the fields supported by MORE, on the other hand are expected to be conducting research as part of their academic programs. In contrast to previous work, the comparisons made in this study are between two groups that are both engaged in scientific research, therefore it cannot simply be the presence or absence of research experience that explain the sharp differences in outcomes. It may be that MORE students are more actively engaged in their research, or that they are provided with greater support by faculty. It is also important to note that while research forms the cornerstone of the MORE programs, it is not the only intervention provided to students.

There is frequent faculty mentoring and advisement, a writing center that provides assistance with theses, academic support, and the opportunity to present and publish research. It is likely that all of these components contribute in varying degrees to the high rates of doctoral study among MORE-supported students.

The success of the MORE programs also point to the role that Master's degree programs can have in preparing students for doctoral study. Many if not most of the graduate students included in this study would not have been strong candidates for doctoral programs had they applied after attaining their undergraduate degree. Thus we conclude that within the large numbers of PhD entrants are students who, were it not for the training and preparation they received in the Master's program, would not otherwise have been admitted.

7. Limitations.

Based on the propensity score matching, it can be stated with confidence that any bias in outcomes associated with the matching variables was sufficiently controlled. This is not to suggest however that all relevant variables were included in the matching, therefore care must be taken in reading the results as the causal effect of MORE participation on student outcomes. While baccalaureate GPA was not included due to excessive missing data, comparing cases for which data was available found no significant differences. Moreover a previous study of MORE and non-MORE supported undergraduates (Slovacek et al, 2012) included entry GPA as a matching variable and found comparable effects of MORE participation on entrance to PhD programs.

There is also the risk of bias due to variables not observed by the study, notably student motivation and intent to pursue a PhD. How likely is it then that the large differences observed between MORE and comparison group students with respect to PhD entrance could be explained by differences in intent to obtain a doctorate? For guidance we can look to Schultz et al (2011), which assessed the impact of the Research Initiative in Science Excellence (RISE) programs (one of the main components of the MORE programs) on intention to pursue a PhD across multiple institutions. The study, which also employed propensity scores, found no differences in the intent to pursue a PhD between those students supported by the RISE program and those in the comparison group prior to the inception of the program, though subsequent differences were found as students progressed through the program.

Moreover, Schultz et al (2011) found that these differences were largely attributable to research experience; conducting research led to gains in intent irrespective of RISE involvement. This demonstrates not only that the intent to pursue a PhD is fluid and malleable (which should come as no surprise), but also that even in cases where data on intent is available, the manner in which that intent can change and be encouraged over time (and the influences thereon) need to be better understood before the extent of the bias can fully be properly assessed.

8. Further Research.

Clearly more attention should be paid to the characteristics of the students participating in the MORE type programs, particularly with respect to motivation the intent to obtain a doctoral degree. Measurements of these characteristics could shed light on the extent to which motivation and intent may bias current estimates of program effectiveness, in addition to determining whether the programs themselves influence these characteristics. Additionally, as most of the current research takes a holistic view of these programs, (that is, examining the impact of the program as a whole), research that examines whether the various components of these programs impact students in different ways is needed as well. In particular, the way in which program components interact with student characteristics, insofar as not every student will participate in or benefit from every component, would likely provide valuable information to those overseeing or seeking to implement these programs.

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Appendix A: Data Sources

Data source	Type of data	Scope
Institutional Data	• Field of Study • GPA • Matriculation date • Graduation • Demographics (age, sex, ethnicity, citizenship) • Enrollment • Drop outs	All graduate students in the College of Natural and Social Sciences, 2000-Spring 2010 N= 4745
MORE Program Offices	• Graduation • Entrance into advanced degree programs	Students funded by one or more MORE programs, 2000- Spring 2010 N = 161
National Student Clearinghouse	• Enrollment in institutions other than the university • Degrees earned at other institutions	All graduate students in the College of Natural and Social Sciences, 2000- Spring 2010 N= 4745
Internet Sources	• Institutions attended • Degrees Earned	MORE and matched comparison group N= 322

Appendix B: Logistic Regressions, Graduation

	Model					
	(1)	(2)	(3)	(4)	(5)	(6)
MOREPart	1.05***	1.04***	1.12***	1.11***	1.70***	1.21
	(0.27)	(0.27)	(0.28)	(0.28)	(0.35)	(0.98)
Matric		-0.09*	-0.10*	-0.10*	-0.11*	-0.13
		(0.04)	(0.04)	(0.04)	(0.05)	(0.05)
Gender:Female			0.89**	-0.85**	0.92**	0.63
			(0.29)	(0.30)	(0.31)	(0.41)
URM			-0.12	-0.14	-0.24	-0.20
			(0.41)	(0.42)	(0.43)	(0.56)
Age			0.02	0.02	0.02	0.02
			(0.03)	(0.03)	(.03)	(0.03)
Ugrd			-0.26	-0.29	0.93	0.98
			(0.33)	(0.33)	(0.49)	(0.50)
Psych				0.23	0.30	-0.17
				(0.35)	(0.35)	(0.48)
Chem				-0.05	-0.08	0.59
				(0.38)	(0.40)	(0.56)
MOREPartXUgrd					-2.16**	-2.48
					(0.65)	(0.69)
MOREPartXFemale						0.75
						(0.61)
MOREPartXURM						0.21
						(0.89)
MOREPartXPsych						0.21
						(0.89)
MOREPartXChem						1.01
						(0.75)
Constant	-0.34***	2.82	1.33	1.32	1.49	3.50
	(0.19)	(1.45)	(1.93)	(1.93)	(1.99)	(2.05)
AIC	321.38	318.46	314.87	319.31	310.13	309.28
N	242	242	242	242	242	242

Appendix C: Logistic Regressions, Acceptance to PhD programs

	Model					
	(1)	(2)	(3)	(4)	(5)	(6)
MOREPart	1.99***	1.95***	1.91***	1.99***	1.98***	2.31*
	(0.49)	(0.52)	(0.52)	(0.54)	(0.54)	(1.04)
Zdeggpa		1.00***	1.04***	1.07***	1.05***	1.16***
		(0.25)	(0.26)	(0.26)	(0.27)	(0.28)
Matric_recoded			0.09	0.10	0.11	0.12
			(0.07)	(0.08)	(0.08)	(0.08)
Gender:Female				-0.54	-0.57	0.49
				(0.49)	(0.49)	(1.00)
Age				-0.03	-0.03	-0.02
				(0.06)	(0.06)	(0.06)
Ugrd				-0.01	-0.12	-0.03
				(0.55)	(0.61)	(0.61)
URM				0.14	0.12	0.04
				(0.69)	(0.69)	(0.69)
Psych					0.22	-1.00
					(0.55)	(1.26)
Chem					0.04	-0.70
					(0.62)	(1.29)
MOREPartXSex						-1.55
						(1.16)
MOREPartXPsych						1.58
						(1.37)
MOREPartXChem						1.11
						(1.48)
Constant	-2.78***	-2.06***	-5.28*	-4.34	-4.46	-5.58
	(0.39)	(0.47)	(2.51)	(3.67)	(3.27)	(3.34)
AIC	154.37	135.44	135.64	141.99	145.83	148.13
N	132	130	130	130	130	130