

ROOTS of STEM

Working Paper Series

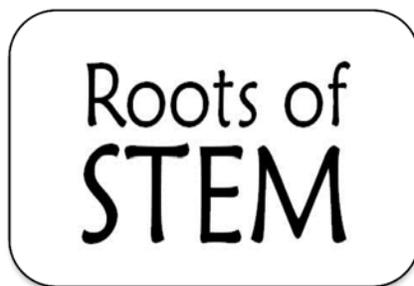
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Growing the Roots of STEM Majors: Female Math and Science High School Faculty and the Participation of Students in STEM

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Abstract

The underrepresentation of women in science, technology, engineering, and mathematics (STEM) fields is problematic given the economic and social inequities it fosters and the rising global importance of STEM occupations. This paper examines the role of the demographic composition of high school faculty—specifically the proportion of female high school math and science teachers—on college students’ decisions to declare and/or major in STEM fields. We analyze longitudinal data from students who spent their academic careers in North Carolina public secondary schools and attended North Carolina public universities. Our results suggest that although the proportion of female math and science teachers at a school has no impact on male students, it has a powerful effect on female students’ likelihood of declaring and graduating with a STEM degree, and effects are largest for female students with the highest math skills. The estimates are robust to the inclusion of controls for students’ initial ability.

Keywords: educational economics, career choices, impact of schooling

JEL Classifications: I21, I24

1. Introduction

The need to expand the science, technology, engineering and mathematics (STEM) workforce has become increasingly pressing in the last 20 years. Although the number of people who earn STEM degrees has increased substantially in the last decade, the supply of the STEM workforce continues to trail the nation's demand. For example, the Bureau of Labor Statistics reported that the U.S. economy is expected to add at least 1.2 million computer science jobs from 2010-2020, but at the current pace, U.S. universities will only produce half the number of U.S. computer science graduates needed to fill those positions (Atkinson, 2013). Currently the mismatch between the STEM workforce supply and the economy's demand is filled by immigrant workers but this is a short-term solution that soon will be neither politically sustainable nor economically efficient (Ehrenberg, 2010). As a consequence, policy makers have openly acknowledged that the United States needs a long-term strategy to ameliorate the shortage of STEM graduates.

One untapped potential for increasing the numbers of STEM graduates is the population of female college students. Women are the majority of college students but represent a distinct minority of STEM degree holders. Although some STEM fields have started to graduate greater numbers of women (i.e., biology), strikingly few young women graduate with degrees in the physical sciences and engineering. This pattern draws attention to a major factor in the STEM workforce supply-demand dilemma: only a small number of women pursue a STEM career pathway. National Science Foundation (2009) statistics report that although women made up the majority of U.S. undergraduates in 2007, colleges and universities awarded only 39% of their STEM bachelor degrees to women. And most of these in the biological sciences. The attrition of

women from STEM fields continues as they move into the labor market where only 27% of STEM related jobs are held by women despite the fact that more than half of U.S. workers are female. Clearly, one strategy to fill the shortage in the supply of STEM workers is to encourage women to pursue STEM careers. Because these careers require specialized higher education, the factors related to the relatively weaker participation of women in college STEM majors are important topics for study.

Prior research has revealed that female college instructors may be instrumental in encouraging women to enroll and excel in subjects in which they are underrepresented (Bettinger & Long, 2005). This body of research has found that the unequal participation by gender in STEM could be explained by a variety of factors including differential societal expectations for boys and girls, where boys receive more encouragement to pursue STEM fields (Ceci and Williams, 2007); a paucity of women role models and/or mentors (including school teachers and college professors) in STEM fields (Sonnert and Fox, 2012); and/or discriminatory environments and chilly climates (Hall & Sandler, 1982). Additionally, young women are likely to indicate that female teachers play important roles in shaping their early interests in STEM (Jackson, n.d.).

There is a large body of research that has examined the importance of female college faculty for the STEM outcomes of women during the college years (Canes & Rosen, 1995; Rothstein, 1995; Bettinger & Long, 2005; Robst, Keil & Russo, 1998; Price 2010; Newmark & Gardecki, 1998; Carrell, Page & West, 2010; Hoffman & Oreopulus, 2009; Kokkelenberg & Sinha, 2010; Rask, 2010). Most of these studies analyze the relationship between the persistence of students in STEM fields and the gender match between college faculty and students (Bettinger & Long, 2005; Price 2010; Robst, Keil & Russo 1998; Griffith 2010). However, many studies also look at the link between women's choices of STEM major with the proportion of female

faculty at the college (Rothstein, 1995; Qian, Zafar & Xie, 2009; Canes & Rosen, 1995; Carrell, Page, & West, 2010).

Studies have indicated some mixed effects related to the presence of female university faculty in the university on female college STEM outcomes. A portion of these studies analyzes the relationship between the persistence of students in STEM with the gender ratio between faculty and students. For example, research has found that the likelihood of female students' taking courses and majoring in mathematics, statistics, geology, sociology, and journalism was significantly higher when they were taught by female faculty (Bettinger & Long, 2005). Previous evidence also shows that the percentage of female math and science teachers in college has a strong positive link to women's retention in science, mathematics and engineering (Robst, Keil & Russo, 1998). At the same time, a study concluded that female students are no more likely to persist in a STEM field when they enroll in courses taught by female faculty (Price, 2010) and another found that female students persistence in STEM fields was unaffected by the gender makeup of the STEM faculty (Griffith, 2010). Recently, Griffith (2014) also found that although major choice and course-taking behavior are mostly unaffected by the gender match between faculty and student, students earn higher grades in courses taught by same-gender instructors in fields traditionally dominated by the opposite gender such as STEM.

Other studies have looked at the overall influence of proportion of female faculty members in college on women's choice of major. Prior research has found a positive association between the percentage of female faculty and the probability that a female student will earn an advanced degree (Rothstein, 1995). Studies have also concluded that as the percentage of female faculty in STEM departments increases, the percentage of four-year degrees awarded to females in these departments will also increase (Qian, Zafar, & Xie, 2009). Furthermore, Carrel, Page &

West (2010), using a randomly assigned sample of college students to professors, found that female professors have a powerful effect on high-performing female students' likelihood of graduating with a STEM degree. However, when Canes & Rosen (1995) analyzed the effect of the proportion of women in a department's faculty on the number of female majors within that department, they found no evidence that an increase in the share of women on a department's faculty led to an increase in its share of female majors. The mixed results regarding the influence of the gender distribution of college faculty on students' STEM outcomes suggests that looking at high school experiences might be able to shed more light on STEM college major choice

There is less research focused on the importance of female teachers during the pre-college years on young women's STEM outcomes. This is surprising given the fact that emerging evidence suggests that the pre-college setting is highly influential on students' choice of major in college (Maltese & Tai, 2011). The majority of studies that focus on pre-college years examine the gender match between teacher and student and its effect on student's non-STEM outcomes, such as achievement and engagement (Dee, 2005, 2007; Winters, Haight, Swaim & Pickering, 2013; Nixon & Robinson, 1999). What is missing from the corpus of research is an analysis of how the proportion of female STEM high school teachers, as a whole, affects students' STEM participation in college.

By looking at the proportion of female math and science teachers at the high school attended by students, we seek to gain insight into a broader picture of the importance of the gender composition of the high school faculty on student outcomes. This paper shifts the attention of the inquiry of the role of women teachers from individual teachers to the proportion of STEM women teachers as a whole and focuses on the importance of these teachers in

students' early academic trajectories. Doing so emphasizes the importance of the cumulative nature of early school experiences and contexts for decisions to pursue STEM majors in college.

We focus on the contextual effects of the gender composition of the math and science faculty in students' high schools because a more diverse climate, in terms of gender, provides an atmosphere that is more welcoming to female students in that it provides greater opportunity to develop teacher and/or peer networks (Robst, Keil & Russo, 1998). These networks also increase the availability for potential role models and/or mentors for girls – resources which are very influential for academic and career success of female students (Butler & Christensen, 2003; Nixon & Robinson, 1999; Day & Allen, 2004). Role models may be especially salient for young women because their behavior appears to be more responsive to the needs and requests of significant others, and to the situational constraints that influence their own and others' behaviors (Cross & Madson, 1997; Author 2003, 2013). Moreover, female role models push girls to take risks (Smith, 2000) and resist stereotypes prescribing gender-role stereotypical jobs for men and women.

Prior studies have also suggested that STEM fields are characterized by a “chilly climate”¹ that is unwelcoming to girls in high school and young women in college, pushing them away from STEM fields in spite of their interest and aptitude (Herzig, 2004; Zhao, Carmi & Kuh, 2005). Faculty gender is a major influence on the factors that comprise measures of culture and climate (Bulach & Berry, 2010), and a higher proportion of female math and science teachers could translate to a friendlier environment in STEM courses (Statham, Richardson & Cook, 1991). Furthermore, when all or most faculty are male, female students come to see success and persistence in math and science fields as fundamentally masculine domains, while concomitantly

¹ This “chilly climate” is expressed as the difficulties experienced by girls in high school and young women in college in terms of the social relations of authority in classrooms and peer networks among other students.

learning to doubt their own competencies in these areas (Eisenhart, Finkel & Marion, 1996; Correll, 2001; Guimond & Roussel, 2001; Lee, 1998). In general, the larger proportion of math and science teachers who are women might increase girls' perceptions of school STEM cultures as more welcoming (Fox, Sonnert & Nikiforova, 2009; Statham, Rochardson & Cook, 1991), less male-biased, and with higher expectations for girls (<http://www.napequity.org/root/school-classroom-climate/school-classroom-climate-theory-evidence-2/>), thereby increasing the odds that young women will enroll in STEM majors in college.

This research adds to the literature several ways. First, we center attention on teachers during the secondary school years, when it is more likely that students lay the academic groundwork for their future college plans - or, in some cases, make up their minds about their likely college majors. Second, we focus on the importance of the gender composition of teachers at the high school, instead of the gender match between student and teacher, thereby investigating possible contextual effects of the gender composition of secondary schools' teacher workforce on choice of college STEM majors. Third, we focus on the gender composition of math and science classes in the high school because these are the subjects most directly related to STEM interest, given that there can be substantial variation in faculty gender composition between subjects in high school (for example, English compared to physics). Fourth, our unique dataset of students who matriculated as freshman at one of the 16 University of North Carolina (UNC) system campuses in 2004 allows us to link an individual's secondary school experiences and characteristics in grades 7-12, as well as college characteristics and experiences, with a host of individual-level and demographic variables. In doing so, we are able to link past lived experiences in homes, communities and at the secondary schools with future college STEM

outcomes. This research design adds a dynamic component to the investigation of the underrepresentation of young women in college STEM majors.

2. Research Question and Hypotheses

This study examines whether the proportion of female high school math and science teachers influences girls' and boys' decisions to declare and/or graduate with a major in a STEM field. Specifically, we expect to test the following hypothesis: The higher the proportion of female math and science teachers at the high school students attended, the more likely female students will be to declare and/or graduate with a STEM major in college. In addition, there should be no significant association between percent female math and science teachers and male students' likelihood of declaring/graduating with a STEM major.

The rationales for our hypotheses about female students are twofold. First, in a context in which the proportion of female teachers in high school reaches a preponderance of the faculty, the "chilly climate" of STEM subjects should diminish, interest in STEM will be seen as less masculine, and therefore girls' propensity to major in STEM should also increase. Second, the greater the proportion of female STEM teachers in girls' high schools, the greater their exposure to available potential role models and/or mentors, and thus they are more likely to emulate their behavior and pursue STEM majors.

3. Data, Variables and Methods

3.1 Data

We analyze a unique dataset to test our hypotheses. The North Carolina Roots dataset contains longitudinal information on the academic performance and scholastic experiences among all 2004 North Carolina public school graduates who also matriculated to one of the 16 campuses of the University of North Carolina system. Data for these individuals includes

student, family, school, and achievement indicators from seventh grade through their college graduation. Additionally, the Roots dataset contains information about the characteristics of the schools and colleges that students attended throughout their educational careers. North Carolina Department of Public Instruction data from grades 7-12 for 2004 high school graduates were provided to the North Carolina Education Research Data Center at Duke University (NCERDC) where they were merged by NCERDC with data on the same students' college experiences provided by the University of North Carolina General Administration. In addition, we utilized College Board information regarding the SAT scores (a composite score of student's performance on the critical reading and mathematics sections), and students' responses to survey questions concerning their academic interests, preparation, etc.

We focus on a racially, ethnically, and socioeconomically diverse sample of 19,000 college-bound students who attended 350 high schools² in North Carolina, and later attended any of the 16 University of North Carolina colleges in 2004.³ Given that only 16,000 actually went on to declare any major, our sample size was further decreased.⁴ We ultimately used a sample of approximately 12,550⁵ students with characteristics similar to our original sample.⁶

² There were no all-girls public schools in our sample.

³ These campuses are: North Carolina Agricultural and Technical State University (NCA&T), Appalachian State University (ASU), University of North Carolina-Asheville (UNC-A), East Carolina University (ECU), Elizabeth City State University (ECSU), Fayetteville State University (FSU), North Carolina Central University (NCCU), University of North Carolina-Pembroke (UNC-P), North Carolina State University (NCSU), University of North Carolina-Charlotte (UNC-C), University of North Carolina-Chapel Hill (UNC-CH), University of North Carolina-Greensboro (UNC-G), Western Carolina University (WCU), University of North Carolina-Wilmington (UNC-W), Winston Salem State University (WSU), and University of North Carolina School of the Arts. North Carolina School of Arts was not included in our analysis because it has no STEM majors.

⁴ We utilize information of the major students declared between the years 2005 and 2011. The vast majority of the students declared their majors when they were in their sophomore or junior year. In several cases students declared more than one major. Importantly, approximately 24% of our sample never declared a major (either dropped out of college before declaring a major, transferred to a community college, transferred to a campus out of the NC system or died) and are not included in our analysis. Therefore our sample is one of college-bound students who at least declared a major and attended middle and high school in NC.

⁵ We excluded approximately 1,400 students who attended schools that offered a program with a math and science focus.

The sample of students we employ in this study is representative of North Carolina's in-state four-year college-going population because most of the students in NC that go to college stay in a college in-state⁷ in part because the UNC system includes very competitive public universities such as UNC Chapel Hill and NC State University. Based on SAT survey data provided to the Roots Project by the College Board, the sample of young men and women included in our study had, on average, higher math and reading SAT scores than the North Carolina students who did not attend college in the UNC system but planned to attend a four-year college when they took the SAT (see Appendix A).

The unequal gender attainment of STEM majors is readily apparent in the UNC system. For the 2004 entering freshman cohort under study, 17 percent of students declared a STEM major, and 19 percent of students who graduated did so with a STEM major. As is commonly the case, young men are overrepresented in STEM majors: although only 43 percent of students in the entire system are male, 57 percent of students who graduated with a STEM major were young men (see Table 1). UNC system-wide, there is an overall 9 point gender gap in the declaration of a STEM major, and a 13 point gender gap in the completion of a STEM major. Young women constitute around 43 percent of students who declared and graduated with a STEM major despite the fact that they make up 56 percent of the state university system's students. The gender gap is most striking in the fields of engineering and computer science where women comprise only 21 and 22 percent of majors, respectively (see Table 2).

[Tables 1 and 2 about here]

⁶ Given the nature of our data we can only generalize these results to the sample of students who attended secondary public school in North Carolina and later pursued their undergraduate studies in the UNC system and have declared a major.

⁷ About thirty-eight percent of North Carolina's high schools graduates reported an intention to attend a public higher education institution and only about three percent of graduates said they planned to attend an out-of-state institution (DPI, 2003).

3.2 Variables

Outcome Variables The dependent variables we employ to test our hypothesis are whether or not a student (1) declared and (2) graduated with a STEM major. We use multinomial dependent variables, where 0 indicates no declaration/graduation of a STEM major, 1 stands for declaration/graduation with a major in biological sciences, and 2 indicates declaration/graduation with a major in any other STEM discipline other than biological sciences (such as physical sciences, engineering and mathematics). We chose a multinomial approach because it is most appropriate given the different demographic composition of students in biology and other STEM disciplines (Newton, Torres & Rivero, 2011). We separate biology from other physical sciences, mathematics, and engineering majors because the biology major does not suffer from an underrepresentation of women found in other STEM disciplines, whereas two-thirds of the students who declare a major in physical sciences, engineering, and mathematics are men.

To define a STEM major, we use the categorization utilized by the National Science Foundation Advance Program (<http://www.nsf.gov/crssprgm/advance/index.jsp>) where majors such as engineering, physical sciences, earth, atmospheric or ocean sciences, mathematical and computer sciences, and biological and agricultural sciences are considered to fall within the STEM category. A variety of both individual and school level variables were included in this study. Their names, means and standard deviations are shown in Table 3.

[Table 3 about here]

Student-Level Variables: Our models include student demographic and family characteristics such as race/ethnicity, gender, and SES (defined as whether student received free-reduced lunch in 7th grade, received a need-based Pell grant in college, and is (or not) a first-generation college student in his or her family). Drawing on factors identified in previous

research (e.g. Bartolj & Polanec, 2012; Federman, 2007) as possible explanations for differential participation rates of male and female students in STEM, we include (a) measures for math SAT scores, (b) whether the student took algebra 1, algebra 2, and biology in an advanced academic track, and (c) and whether the student took physics during high school. We also utilize math SAT scores to categorize students into students with high math ability and students with low math ability. Indeed, Carrell, Page & West (2009) find that the gender of the professor has a powerful impact on female students' performance in math and science classes that is even largest for female students with very strong math skills.

School-Level Variables: Our key independent variable is the proportion of science and math teachers who are women among the math and science faculty of the high school from which each student graduated. We focus specifically on the math and science teachers because these are the ones who could be available to serve as possible role models, mentors, or who could most directly challenge the “chilly climates” towards STEM that might otherwise exist at the high school. In addition, because students are required to take algebra 1, algebra 2, and biology, we can be certain that there was at least some interaction between these teachers and students.

We use the proportion of female math and science teachers as a measure of the opportunity for female students to identify with female role models or mentors in the field, as well as for the likelihood that there was a neutralization of the possible “chilly climate” towards STEM at that school. We use data on each high school classroom's personnel to calculate the gender composition of the math and science⁸ teachers at each high school between 2000 and

⁸ Based on the State Course Code Subject Area, which indicates the state-defined subject area to which this teachers' activity can most closely be associated, we determined each teachers' subject area of instruction. We also used the Outline of the Course Coding Structure for NC Public Schools 2005–2006, which defines the discipline of the

2004. We then calculate the average proportion of female math and science teachers over the years the student is in high school⁹.

On average, across the 270 high schools included in the study, 63 percent of the math and science teachers were women (68 percent of the math teachers were women and 56 percent of the science teachers were women) compared to 80 percent women teachers in all subjects in the state of North Carolina.¹⁰ Although over half of North Carolina's secondary math and science teachers are women, female representation is proportionally lower than in these disciplines than it is in other subject fields such as English or social studies. When we divide the sample of high schools into terciles based on the distribution of proportion female math and science teachers the average for the schools with low representation of female math and science teachers is 47 percent, the middle tercile has an average of 63 percent math and science female teachers, and the highest tercile has an average of 75 percent female math and science teachers (see Table 4).

Because we were also concerned about possible issues of bias and causality, we also included other control variables at the school level to show that the variation in our main explanatory variable is not correlated with other school characteristic (such as students' gender and ability). Table 4 shows that the measure of female math and science teachers is essentially

subject. We categorized all of those teachers in the disciplines of mathematics and science as math and science teachers. Then we determined the proportion of women teachers among all of the math and science teachers in each of the high schools. This variable measures the exposure that students had to a math and science faculty with various proportions of females during secondary school.

⁹ We also tried our models using as key independent variable the percentage year when each student took most of their math and science classes and assign that specific value as their proportion female math and science teachers. Because the gender composition of the math and science faculty at a school does not change substantially from one year to another results were almost the same.

¹⁰ Although nationally the gender distribution of public school teachers is 76 percent women and 24 percent men, the gender composition is substantially different when one looks at the subjects of high school math and science. Data from the School and Staffing Survey (2008) suggest that in 8th and 12th grades, 65 percent and 52 percent of the teachers in math were women, respectively; and 52 percent and 44 percent of the science teachers were women. Similarly, the gender distribution of teachers in the state of North Carolina in 2000 was unequal. Across all public school teachers in NC, 80 percent of them are women, and the percentage of women math and science teachers altogether in 10th grade totaled 64 percent (Roots Data, authors' calculations).

uncorrelated with other teacher or student characteristics at the school level. More specifically, schools in the lowest tercile of the distribution of the percent of female math and science teachers have on average 49% of female students, precisely the same percentage as schools in the middle and higher tercile. In addition, schools across the three different terciles of the female math and science teacher distribution share an almost equal level of academic achievement among students and nearly equivalent teacher characteristics (such as teacher turnover, teachers' experience, teacher with advanced degrees, etc.) The nonexistent correlation of the treatment (percent female math and science teachers) with other school level variables provides support for believing that the estimates of the models are indeed picking up the causal effect of female faculty and not just a correlation caused by some other school factor or student characteristic.

[Table 4 about here]

In all models, we also control for variables correlated with probability of declaring and/or graduating with a STEM degree and our primary independent variables. These controls include racial composition of the school (proportion of white students at school); proportion of female students in the school (recognized as an important characteristics for school choice of female students by Schneeweis & Zweimuller (2012)); proportion of students in advanced college preparatory courses (see Ost (2011) for a study that looks at the importance of quality of peers' grades and retention in STEM at the college level); and school locale (urban, suburban, or rural). In addition, we include a set of variables that aim to capture important aspects of the high school that could be associated with students' interest in STEM, including measures of teachers' experience, teachers' education, and teacher turnover (percent of teachers employed in a school when the students are in a grade who are no longer employed in the same school when students are in following grade). All of these school level variables were included as averages of the years

the majority of the students were in high school (2000-2004). Controlling for these confounding variables helps increase the reliability of our finding regarding the effect of proportion of female math and science teachers. Table 3 provides descriptive statistics of all of these variables¹¹.

3.3 Empirical Methods

To address our research question, we utilize multilevel multinomial models using the GLIMMIX procedure in SAS where the dependent variable has a multinomial distribution and a logit link function for non-normal residuals. We employed multinomial logistic multilevel regression analysis because the outcome variable was coded as one of three categories: declaring (1) a physical sciences, engineering or mathematics major, (2) a biology or agricultural sciences major, and (3) a non-STEM major. Multilevel multinomial regression analysis is appropriate for this analysis because it allows comparison of more than two groups, and is therefore an extension of multilevel logistic regression that compares only two groups. In addition, we also utilized multi-level models because we are worried that the individual level error term might be correlated between individuals at the same high schools. Multi-level models assume a different variance structure at each level of analysis, and regression coefficients and standard errors can be estimated at each level (student- and school-level) without bias. The two levels we are using in our models are individual (student) and high school level. With our models we examine students'

¹¹ We conducted additional analyses (not shown) including college-level variables. There is evidence that institutional characteristics affect STEM related decisions in college (Griffith, 2010). 60% of the STEM students in our sample attended UNC-Chapel Hill or NC State University. For this reason, the two flagship institutions represent the excluded category in our analysis. We first ran the colleges separately but the models would not run due to small cell sizes. Therefore, we created five different categories of colleges: other large predominantly white institutions (ASU, UNC-C, ECU, UNC-W, UNC-G,); small predominantly white institutions (WCU, UNCA, AND UNC-P), historically black colleges (NCA&T, ECSU, NCCU, WSSU, and FSU), Prestigious and flagship institutions (UNC-Chapel Hill and NCSU) to control for specific institutional characteristics of these colleges that might have a relationship to our outcome.

chances of graduating and/or declaring a STEM major during the years 2005-2011¹². The hierarchical multinomial models allow us to examine the effect of school characteristics that impact college students' decision to declare a STEM major, taking into consideration the fact that certain groups of students attended the same high schools. The basic econometric model is presented in Equation 1.

Equation 1. Multilevel multinomial logit model assessing probability of enrollment and graduation with STEM majors by student and secondary school characteristics

The multilevel multinomial logit model is a mixed Generalized Linear Model with linear predictors:

$$\eta_{ij}^{(m)} = \alpha^{(m)} + \beta^{(m)'} x_{ij} + \varepsilon_j^{(m)} + \delta_{ij}^{(m)}$$

And multinomial logit link:

$$P(Y_{ij} = m | x_{ij}, \varepsilon_j, \delta_{ij}) = \frac{\exp\{\eta_{ij}^{(m)}\}}{1 + \sum_{l=2}^M \exp\{\eta_{ij}^{(l)}\}}$$

Where $m=1, 2$ or 3 denotes the major category (non-STEM, biology, or physical sciences/engineering/mathematics [PSEM]), $j=1,2, \dots, J$ ($J=322$) denotes the cluster (high school) and $i=1,2,\dots,n_j$ denotes the subject (student) of the j -th cluster. The response variable Y_{ij} has (conditional on the random effects) a multinomial distribution, taking values in the set of categories $\{1,2,3\}$ where $m=1$ denotes the reference category (non-STEM major) for which all parameters and the random errors are set to 0 and thus the conditional probability of $Y_{ij}=1$ is

$$\frac{\exp\{\eta_{ij}^{(1)}\}}{1 + \sum_{l=2}^M \exp\{\eta_{ij}^{(l)}\}}. \text{ Each equation has specific parameters } \alpha^{(m)} \text{ and } \beta^{(m)}. \text{ Finally, } \varepsilon_j \text{ and } \delta_{ij} \text{ are}$$

¹² Our tables also show additional results with models that control for categories of college campuses in the NC University System to control for college group fixed effects. We do so to isolate the treatment effect that does not operate via college choice.

vectors of random errors representing unobserved heterogeneity at the cluster and subject level, respectively. Students' chances of declaring and/or graduating with a PSEM or biology major are a function of student individual characteristics, and high school variables. We estimate the model using different samples depending on sex and ability levels (based on math SAT scores); we use school-level variables centered at the grand mean. We ran separate analyses for each outcome (those who declare and those who graduate from a STEM major). Such an approach permits us to look at both at short-term (major declaration) and long-term (major completion) effects for college students.¹³

4. Results

4.1 Short-Term Effects (Declaring a STEM Major)

Previous research shows that the majority of the students who pursue STEM degrees make this decision during high school (Maltese & Tai, 2011). Therefore, students' high school experiences are important for understanding college STEM outcomes. We investigate, in particular, the relevance of the gender distribution of their math and science teachers in the choice to major in STEM. Because the majority of students are non-STEM majors, we use non-STEM as the baseline category; the two logit equations will then describe the log-odds that students declare a major in the biological sciences or the physical sciences, engineering, or mathematics field, as opposed to a non-STEM area.

Table 5 reports average marginal effects from results of the probability of declaring a STEM field major using the Roots sample. We first estimate a model with the entire sample of

¹³ In the cohort of NC university system students that we analyzed, 24 percent of the students who initially declared a STEM major never graduated with a degree in that field.

12,450 students and then estimate models separately by gender (for the 7,250 women in the sample, and then for the 5,370 men). The first four columns of Table 5 show the estimated effects for all students, whereas the other columns focus on subsets of female students with different levels of math skills. We start by providing models with no controls, then with individual-level controls, and finally models that include individual- and school-level controls for the full sample of students. By doing so, we are able to examine the extent to which the percent female math and science teachers at a school correlates with other unobserved factors. We then present the models including individual- and school-level variables for the sample of female and male students. Furthermore, we look at different subsamples of female students by perceived math ability.¹⁴

[Table 5 about here]

We first look at the results for the entire sample. Models 1 to 4 show the positive and significant relationship between percent female math and science teachers and students' chances of declaring physical sciences, engineering and/or mathematics as a major. Because estimates change little when individual- and school-level controls are introduced, we can safely assume that there are no unobserved cofounders. Declaration of STEM as a major differs significantly between women and men. Men are much more likely to declare a PSEM major than women, although women are more likely to declare biological sciences as a major. Asian and American Indian students have higher probabilities of declaring STEM majors than White students in our sample. Students with better prior academic achievement as measured by math SAT scores, those who enrolled in advanced algebra II classes when in high school, and those who took physics in high school are more likely to declare a STEM major.

¹⁴ We do not present results for male students by perceived math ability because our key independent variable is not significant, therefore there are no interesting findings to discuss.

Importantly, our findings indicate that attending a school with a higher proportion of female math and science teachers at a school is related to a significant increase in the chances of declaring physical sciences, engineering, or mathematics as a major. Other high school characteristics are also important as well. For example, if a student's high school was located in a rural or suburban area rather than in an urban area, students had higher odds of declaring a STEM major. Attending a school with a higher percentage of students in advanced academic tracks increased students' chances of declaring a biological science as a major while it reduced their chances of declaring a PSEM as a major.

The estimated effect of proportion female math and science teachers at a high school varies across the sub-samples of students. As we anticipated, attending a school with a higher proportion of female math and science teachers appears to inspire girls to declare a STEM major (in both biology and PSEM), while having no significant association on boys' STEM major declaration. No significant effects were found regarding the importance of female math and science teachers and the odds of declaration of STEM of high skilled girls or low skilled girls. Other school-level variables regarding teacher characteristics were not consistently significant across subsample of students.

4.2 Long-Term Effects (Graduating with a STEM major)

We now turn to our analysis of the possible influence of proportion female math and science high school teachers on college students' likelihood of graduating with STEM majors. We understand that the decision to graduate with a STEM major involves additional factors that go beyond the experiences student had during their high school years. These additional variables include college experiences and characteristics that could influence students' decision to stay in their STEM majors as suggested by prior research (Griffith, 2010; Price, 2010; Maltese & Tai

2011). To control for those possible influences, we include results of one model with the entire sample of students that includes fixed effects for groups of college campuses. Table 6 presents findings from our models predicting the chances that students graduate with a STEM major compared to not graduating with a STEM major. Findings show that the influence of proportion of female math and science teachers is even stronger for students' odds of graduating with a STEM major than for students' chances of declaring a STEM major. In this case, a higher proportion of female math and science teachers at a high school are not only related to students' chances of graduating with a PSEM degree, but they also show a significant association with students' odds of graduating with a biological sciences degree. For example, when we calculate predicted probabilities based on the estimates of our models when variables are at their mean value, we find that when students move from attending a school that has a proportion of female math and science teachers of .54 (1 s.d. below) to one that has a proportion of female math and science teachers of .72 (1 s.d. above) their chances of *graduating* with a Biology and a PSEM major increase in 18%, while their chances of *declaring* a PSEM major increase 14% (See Appendix B).

[Table 6 about here]

Additionally, following Carrell, Page & West (2009), we focus on the sample of students that enter college with the highest observed math skills who are the ones that have the most appropriate academic preparation to continue a career in STEM. We conducted the analysis for the top tercile of students based on their math SAT scores (a math SAT score of 580 or higher). Results in Table 6 show that the estimated marginal effects of the proportion of female high school math and science faculty are larger and stronger for the sample of high-skilled women's chances of declaring physical sciences, engineering and mathematics and biology as a major. For

the case of high skilled women, their chances of graduating with a Biology and PSEM major increases in 36% when they move from attending a school that has a proportion of female math and science teachers of .54% (1 s.d. below) to one that has a proportion of female math and science teachers of .72 (1 s.d. above). Again, results for men are insignificant. Because our models control for initial SAT math scores and advanced math and science placement (taking advanced biology and taking physics) it is unlikely to reflect men's higher likelihood of scoring at the very top of the distribution prior to college. We also ran models for the sample of young women in the bottom two terciles of math achievement, operationalized as SAT math scores. For these students, the proportion of female math and science teachers has no significant association with women's chances of graduating with STEM. These results suggest that the benefits of having higher proportions of female math and science teachers in high school are restricted to the highest-skilled women.

4.3 Biological Sciences vs. Physical Sciences, Engineering and Mathematics (PSEM)

There are important differences in the participation of women in biological sciences as opposed to the PSEM fields. Women have a much higher representation in the biological sciences than in PSEM, where their participation is marginal. Our findings show that the relationship between proportion of female math and science teachers in high school and women's STEM declaration and graduation from STEM fields is larger and stronger for PSEM majors specifically. Furthermore, when we analyze results by female students' levels of observable math skills, we find that the proportion of female math and science teachers in high school is significantly and more strongly linked with higher-skilled female students' odds of declaring and graduating with a PSEM degree (compared to their chances of declaring and graduating with a Biology degree).

Three important features of these findings require our attention. First, all female students' likelihoods of majoring in a STEM field are positively affected by attending a high school whose math and science faculty has a larger female membership. Second, the level of a female students' math skills moderates the significance of her high school female math and science faculty's influence: those with higher skills are likely to pursue PSEM or biology majors, while young women with less developed math skills are not significantly influenced this way. Third, male students' likelihoods of majoring in a STEM field are unaffected by attending a high school whose math and science faculty has a larger female membership.

5. Discussion

Our findings lend support for our hypothesis that women who attend high schools with a higher proportion of female math and science teachers are more likely to declare and to graduate with a STEM major in college. Unlike the STEM-related college faculty, who are primarily males, it is important to keep in mind that the majority of high school math and science teachers are, in fact, female. Nonetheless, even though the majority of North Carolina high school math and science teachers are females, the proportions of female teaching math and science are lower than the proportions who teach other subjects.¹⁵ And, although the majority is women, not all high schools have similar proportions of female faculty teaching math and science classes, as our tercile analysis revealed. Together these findings suggest that a preponderance of female math and science faculty may be necessary for countering the pervasive gender stereotypes that math

¹⁵ Although nationally the gender distribution of public school teachers is 76 percent women and 24 percent men, the gender composition is substantially different when one looks at the subjects of math and science in high school. Data from the School and Staffing Survey (2008) report that in 8th grade and 12th grade, 65 percent and 52 percent of the teachers in math were women, respectively; and 52 percent and 44 percent of the science teachers were women. Similarly, the gender distribution of teachers in the state of North Carolina in 2000 was unequal. Across all public school teachers in NC, 80 percent of them are women and 20 percent are men, and the percentage of women math and science teachers altogether in 10th grade totaled 64 percent (Roots Data, authors' calculations).

and science are masculine domains, especially for the female high school students who score most highly in math.

Although our data do not permit us to investigate the mechanisms that underlie this relationship, we speculate that two different, but related, processes are at work. First, by having a preponderance of female math and science teachers in high school, the “chilly climate” toward STEM decreases and provides a positive normative atmosphere for young women’s interest to be expressed without fear of negative social sanctions. Second, a preponderance of female math and science teachers in high school offer young women greater availability of role models or mentors who could encourage them towards a STEM major and later, a STEM-based career. Because of the gender distribution of math and science faculty at high schools, we know that adolescent girls are actually more likely to find a same-sex math or science teacher than boys (unlike female students at college campuses). Therefore our findings lend less support for an explanation build upon role model theory; instead, we interpret our findings as support for an explanation that draws upon the undermining of the “chilly climate.”

Regarding the significantly stronger influence of female high school math and science teachers on higher-skilled female math students’ odds of choosing a STEM major compared to lower-skilled girls, we speculate that students with stronger mathematics skills are better positioned to succeed in STEM majors that tend to be more mathematics-based. Therefore they may be more susceptible to other factors’ influence (in addition to ability) in their decision to major in STEM. For instance, a high school student with strong math ability may just need some encouragement or some indication that she could succeed while majoring in STEM, while a lower-ability student would need both academic support and encouragement/indication that she could success in majoring in STEM.

An additional striking finding that our quantitative data do not allow us to investigate more completely concerns the gender difference in the relationship of the proportion of female high school's math and science to the likelihood a student will major in STEM. Our theory suggests that more female math and science teachers should inspire girls to enter STEM, but this should have no impact on boys. In fact, our analysis shows that although a number of expected factors predict a STEM major choice among our sample of male college students, the proportion of their high school's math and science faculty who were women had no significant effect. This non-significant effect for boys is again evidence that omitted variable bias is not driving our results.

6. Conclusions

The increasing demand for a STEM workforce and the insufficient supply produced by American educational institutions has led many researchers and policy analysts to focus on the shortage of women in these important fields. Too few female students appear interested in pursuing degrees in science, technology, engineering or mathematics, and even if they have a strong interest, too few remain in STEM majors once they arrive in college. The results from this study replicate earlier findings (Crisp, Nora & Taggart, 2009) that point to the crucial role that secondary school factors have in addressing this problem. We advance this literature by showing that the gender composition of high school math and science faculties has an important relationship to whether or not young women will pursue STEM degrees once they arrive at college. Although previous studies have analyzed the importance of the gender composition of the college faculty on postsecondary STEM outcomes, there has been little empirical research on the importance of female teachers in the early pre-college years on postsecondary STEM outcomes.

Our study is the first to analyze the importance of the gender composition of high school math and science teachers on students' STEM participation during college. We use a sample of students who attended NC public high schools and later enrolled in one of the 16 campuses of the NC university system and declared a major. The longitudinal nature of the Roots of STEM dataset allows us to examine the roles of individual, pre-college and college level characteristics on the participation of students in STEM majors. Results show that young women's pre-college experiences can have an important impact on their decision to declare and graduate with a STEM major. Specifically, our results show that secondary school exposure to faculties with a preponderance of female math and science teachers is particularly important for young women's STEM outcomes. Higher proportions of female math and science teachers in high school increase young women's probability of declaring and graduating with a STEM degree, while secondary school faculty gender composition has no significant effect on young men's odds of declaring or graduating with a STEM major. Even more strikingly, our results show that the positive influence of attending a high school with a higher proportion of female math and science teachers is stronger and greater for the participation of higher-skilled young women (those with math SAT scores in the top tercile of the distribution) in the physical sciences, engineering and mathematics fields and in biology.

Previous research has found mixed evidence regarding the influence of the gender of college faculty on STEM outcomes in college. Nevertheless, when the focus of such analysis is limited to math and science college faculty (rather than the entire college faculty), researchers obtain findings similar to our own: the gender composition of the math and science faculty is significantly associated with female students' chances of participating in STEM. This relationship is even stronger for high-skilled young women. Our findings support those of Carrell,

Page & West (2010) regarding the importance of math and science college professors' gender on women's STEM participation. Furthermore, our results also extend their findings because we link theirs to research showing that the majority of the students who concentrate in STEM make that choice during high school (Maltese & Tai, 2011; Schneeweis & Zweimuller, 2012). Our findings offer empirical evidence that highlights the influential role of a preponderance of female math and science *high school* teachers on short- and long-term STEM outcomes.

There is something about high schools that have very high proportions of female math and science teachers that have a powerful effect on the STEM interest of highly skilled young women—with virtually no expense incurred by their comparable male peers. We speculate that it is important at the pre-college years to help break stereotypes about who are the individuals suitable for a job in science, technology, engineering and mathematics. Our findings suggest that increasing the proportion of female instructors, particularly in math and science subjects might be an efficient way of making the STEM environment at schools friendlier for girls.¹⁶ In case hiring more women is not an option, high schools should aim to make of the math and science environment at school one that is more normative for girls and that implements a pedagogy designed to be more inclusive of females (that could be what girls get when they attend schools with very high proportions of female math and science teachers) that could contribute to fostering the STEM interest in girls, particularly high skilled girls. There is a need to further explore what other possible benefits attending a high school with very high proportions of female

¹⁶ The most important limitation of this study is the that our data do not permit us to investigate why a preponderance of female high school math and science teachers has a positive relationship to STEM majors among female undergraduates, especially the students with the highest mathematics skills; and why the effects are absent for male undergraduates. The larger project from which this study is drawn has a qualitative component that the authors are conducting. In-depth interviews of 317 seniors across the 16 UNC campuses have been completed and are being analyzed as of this writing. The qualitative data should shed light on the unanswered questions raised by our findings reported in this paper. Future research should pursue answers to these questions.

math and science teachers offers to girls' interest in STEM. Based on our evidence, we emphasize the importance of providing women with early opportunities to attend schools that challenge long-entrenched gender stereotypes about math and science. Doing so will likely sustain and support greater numbers of young women pursuing the very rewarding academic and economic careers in science, technology, engineering and mathematics surge. In these ways, greater numbers of women in STEM majors and, later, in STEM careers will grow the roots of STEM careers. Our findings suggest they will contribute to a virtuous cycle of more female incumbents in STEM careers, more female role models, and stronger challenges to any lingering fictions that science, technology, engineering, and mathematics are not for young women.

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