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The More Things Change, the More They Stay the Same? Prior Achievement Fails to Explain Gender Inequality in Entry Into STEM College Majors Over Time

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This article investigates the empirical basis for often-repeated arguments that gender differences in entrance into science, technology, engineering, and mathematics (STEM) majors are largely explained by disparities in prior achievement. Analyses use data from three national cohorts of college matriculates across three decades to consider differences across several indicators of high school math and science achievement at the mean and also at the top of the test distribution. Analyses also examine the different

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comparative advantages men and women enjoy in math/science versus English/reading. Regardless of how prior achievement is measured, very little of the strong and persistent gender gap in physical science and engineering majors over time is explained. Findings highlight the limitations of theories focusing on gender differences in skills and suggest directions for future research.

KEYWORDS: achievement, gender, math, postsecondary, science

The fields of science, technology, engineering, and mathematics (STEM) enjoy a preeminent status in modern society due to their vital role in promoting and sustaining economic prosperity. The past decade has witnessed a reinvigorated national emphasis on education in these fields, driven in large part by concerns that there will be a shortage of individuals qualified to meet the projected growth of STEM occupations (National Academy of Sciences, 2007). Current conversations about lack of gender equality in STEM fields, as evidenced by the relatively low share of scientists who are women, often center on the need to increase the number of females entering postsecondary programs in STEM as a crucial solution to address the future workforce needs of the nation while at the same time recognizing that continued stratification is an issue of social justice (Fox, Sonnert, & Nikiforova, 2011).[1]

Although an interest in promoting women's participation in STEM fields is far from new and a large body of literature exists on the topic, there are nevertheless issues that require further investigation if we are to move toward a better understanding of these gendered patterns. In this article we critically examine a common explanation for women's underrepresentation in STEM fields of study (and subsequently related occupations), namely, that inequality is mostly a consequence of gaps in achievement at earlier points in the life course. This supposition is often offered by researchers studying inequality at earlier ages and put forth as common knowledge (Fryer & Levitt, 2009; Lubinski & Benbow, 1992; Penner & Paret, 2008; Wai, Cacchio, Putallaz, & Makel, 2010; Wilson & Boldizar, 1990). Yet there are few empirical studies that actually test this assertion with nationally representative data, and those that do find little in the way of supporting evidence (Riegle-Crumb & King, 2010; Williams & Ceci, 2007; Xie & Shauman, 2003). If arguments about female underachievement as a principal cause of gender inequality in STEM postsecondary fields are indeed not well founded, then it is problematic for studies to continue invoking them. By doing so we risk placing too little focus on the development of new research and policies that might effectively redress inequality in STEM fields while at the same time exaggerating or at least mis-specifying the consequences of small gender differences on certain measures of achievement during primary and secondary school and perhaps inadvertently perpetuating gender stereotypes in the process.

Consequently, our study aims to provide a critical and thorough examination of the extent to which prior achievement can explain inequitable levels of gender representation in STEM fields of study. We move beyond a consideration of average gender differences in achievement in math and science as a key mechanism for subsequent inequality (Riegle-Crumb & King, 2010; Xie & Shauman, 2003) to explore two alternative conceptualizations of achievement that are less studied but potentially more informative. First, we examine the possibility that the relationship between academic background and the decision to major in a STEM field is nonlinear, such that gender differences at the top of the test score distribution matter most for understanding subsequent gender inequality in fields of study (Robinson & Lubienski, 2011). To the extent that students at the upper tail possess the strongest ability and relevant skills, gender differences among this group could have implications for the gender distribution of STEM college majors. Additionally, we test the idea that it is not *absolute* levels of math and science achievement that are important to explaining gendered postsecondary patterns, but rather individuals' *relative* strengths in math/science versus non-math/science fields, or what we refer to as comparative advantage (Barone, 2011). This perspective emphasizes the potential relevance of within-person comparisons in contrast to most prior research on STEM that privileges only between-group comparisons (Eccles, 2007). Finally, we examine patterns over the past several decades, a time period when women have made substantial progress in postsecondary attendance to the point of now outpacing men (Buchmann & DiPrete, 2006). This comparative perspective will provide new empirical information about the degree to which underachievement arguments have (or have not) been useful for understanding gender patterns in STEM representation across time.

We utilize survey and transcript data from three nationally representative cohorts of college matriculates in the 1980s, 1990s, and early 2000s (from the High School and Beyond Study [HS&B], the National Education Longitudinal Study [NELS], and the Educational Longitudinal Study [ELS], respectively). We concentrate on students' declaration of physical science and engineering majors (including math and computer science), as these fields exhibit strong gender disparities in enrollment, in contrast to the generally equitable patterns observed in the biological sciences (National Science Board, 2008). Our results indicate that regardless of how we measure achievement in high school, accounting for the relatively small disparities between males and females found across all three cohorts does very little to explain gender disparities in choice of a physical science/engineering (PS/E) major, a difference that remains strong and robust over time. We conclude by considering the limited utility of theories focusing on gender differences in skills and abilities and suggest how theories of gender as a social structure, which call attention to how inequality is produced at the individual, interactional, and institutional levels, may be more useful in motivating future research that effectively explains gender disparities in STEM postsecondary fields (Risman, 2004).

Background

In an influential early report titled *Who Will Do Science*, Berryman (1983) likened the long path to an occupation in STEM fields to a pipeline that begins early in students' educational careers and progresses through high school, into and out of college, and eventually ends in the labor force. While some recent studies have rightly critiqued this notion of the pipeline as too singular and simplistic (Xie & Shauman, 2003), there is clearly a connection between academic performance at earlier stages and performance and persistence at later stages of educational trajectories such that math and science achievement in middle and high school strongly predict pursuit of a STEM degree.[2] Drawing on this link, Berryman reviewed research from the 1960s and early 1970s and surmised that opportunities for girls to enter STEM majors in college were curtailed because of their relatively weak math preparation in high school, as manifest in their lower math test scores in 12th grade, which were in turn the result of girls taking fewer advanced math classes than boys. Berryman's argument that inequitable representation in STEM college fields was the result of female underachievement at earlier points in the pipeline was supported with earlier empirical work (Dunteman, Wisenbaker, & Taylor, 1979; Goldman & Hewitt, 1976).

The theoretical perspective that underlies this argument is rooted in rational actor and human capital theories of gender differences in fields of study. Through this lens, college major is a choice made by individuals who seek to maximize the returns to their skills and efforts (Jonsson, 1999; Paglin & Rufolo, 1990). If females have lower average levels of math and science achievement or aptitude, then their success in STEM fields is less likely, or at the very least more difficult to achieve. Another perspective supporting this argument is the theory that scientific disciplines are defined by norms of universalism, such that entry and success are open to anyone who demonstrates skills and talent based on impersonal, objective, and measurable criteria (Merton, 1973). According to this perspective, entrance into and success in STEM majors is conditional solely on successfully completing certain courses and demonstrating merit through test scores and grades; gatekeepers presumably find additional social and background characteristics irrelevant (Long & Fox, 1995). Such ideas provide an explanation for gender inequality during the later stages of the STEM pipeline that appears meritocratic and just, and perhaps more clear and concrete when compared to more abstract theories of gender as a social construct or structure (a topic to which we will turn in the Conclusion).

Within the vast literature on gender inequality in STEM fields published in the past several decades, there are conflicting accounts of the continued validity of female underachievement arguments as a primary cause of gaps in college and beyond. On the one hand, a host of studies repeatedly invokes this argument as the rationale for a continued focus on gender differences in the elementary and secondary years (Fryer & Levitt, 2009; Good, Aronson, & Harder, 2007; Hedges & Nowell, 1995; Leahey & Guo, 2001; Lubinski & Benbow, 1992; Muller, Stage, & Kinzie, 2001; Oakes, 1990; Penner & Paret, 2008; Wai et al., 2010; Wilson & Boldizar, 1990). Indeed, according to Xie and Shauman (2003), the under-representation of females in STEM fields as adults is "the most frequently cited justification for continuing to study math and science gender gaps" (p. 35) and is prevalent among studies in education, sociology, psychology, and economics. For example, researchers studying the effect of stereotype threat contend that gender gaps in test scores are important because they lay the foundation for women's underrepresentation in science at the postsecondary level (Good et al., 2007). Sociologists offer the same explanation for investigating gender differences in high school math test scores (Hedges & Nowell, 1995; Leahey & Guo, 2001). This argument is also prevalent in studies of students as young as elementary school (Fryer & Levitt, 2009; Penner & Paret, 2008). It is interesting to note that these studies offer widely divergent theories as to the cause of the slight gender gap in primary and secondary achievement that they observe; yet they converge by endorsing the idea that these differences have important consequences for female underrepresentation in STEM college fields.[3]

Yet in contrast to the assertions of the research described previously, other studies explicitly call attention to the fact that while some gender differences in STEM achievement persist, they are generally quite small in magnitude and not likely to be consequential.[4] For example, Hyde and her colleagues (Hyde, Lindberg, Linn, Ellis, & Williams, 2008) found that in recent years, the average gender gap on state math assessments has diminished to only one-tenth of a standard deviation in magnitude. Likewise, the gender gap in advanced course-taking implicated in Berryman's (1983) study has virtually disappeared in recent decades (Dalton, Ingels, Downing, Bozick, & Owings, 2007). Grades are another important dimension of prior preparation, and one where girls generally outscore boys even in the subjects of math and science (AAUW, 2008; Ewert, 2010). Indeed, two recent studies that focused on empirically investigating the extent to which prior disparities explain gender inequality in college STEM fields concluded that the evidence does not support this notion. Using data from HS&B, Xie and Shauman (2003) found that while prior academic preparation in math and science is strongly related to entrance into a STEM major, the small gender differences favoring males in this cohort were inadequate to explain the gap in field of study at the postsecondary level. Analyses using data from a more recent national cohort found similar results (Riegle-Crumb & King, 2010).

These prior studies cast doubt on the feasibility of prior achievement as an explanation of gender differences in entrance into STEM fields. Yet they cannot be considered exhaustive in their ability to refute underachievement arguments. In this study, we therefore seek to offer a critical, rigorous, and comprehensive examination of the validity of such arguments with the intent of helping to resolve this inconsistency in the literature. To do so we retain the focus on individual skills that underlies previous work but move beyond a focus on differences at the mean to further consider conceptualizations of academic performance that might provide a more powerful account of gendered postsecondary paths. Additionally, we consider patterns across cohorts of high school students from the last several decades to discern whether underachievement arguments may be more or less relevant at different periods.

Further Considerations of Gender Inequality

With regard to test scores, differences between male and female students are generally observed to be larger in size toward the upper end of the distribution, where males are disproportionately represented (Benbow & Stanley, 1982; Feingold, 1992; Hedges & Nowell, 1995). Seen through the lens of individual skills–based explanations of choice of field of study, this asymmetry at the upper end of the test score distribution may be consequential for later gender patterns, as the highest achievers may have the best chances for successfully meeting the demands of postsecondary STEM majors as well as signaling and attracting the notice of STEM gatekeepers such as faculty, counselors, and recruiters (Xie & Shauman, 2003).[5] Two recent articles (Penner & Paret, 2008; Robinson & Lubienski, 2011) invoked this rationale for studying gender disparities at the top 5% and 10% of the test score distribution among elementary school students; but as with most research on test score gaps, the authors focus on attempting to explain the source of the gap and not on examining its consequences. In this article we therefore investigate the proposition that gender differences in the concentration of students in the upper tail drives subsequent inequality by employing an empirical model that allows the relationship between test scores and STEM participation to vary across the achievement distribution.

Additionally we consider the possibility that relative rather than absolute levels of prior academic achievement may be more useful for understanding subsequent postsecondary gender patterns in fields of study. Barone (2011) notes that while average gender differences in math and science achievement have decreased, girls continue to outperform boys in the humanities, and he suggests that such differentials might play an important role in entrance into STEM fields. This notion of comparative advantage is consistent with theories on the social-psychological aspects of performance, including confidence and self-efficacy, as put forth by Eccles (1994, 2007). She argues that within-person comparisons are much more relevant to understanding individuals' trajectories than between-group mean-level comparisons. Yet like other arguments about the centrality of gender differences in skills, this idea is also consistent with rational actor theories, such that students are attuned to their relative strengths and use them to assess the probability of success and the amount of effort required when comparing different options for their futures (Correll, 2001; Jonsson, 1999). From this perspective, to the extent that males are likely to have stronger math and science skills compared to their skills in reading and English, and females generally have skills weighted in the opposite direction, both genders select a major consistent with their achievement profile. Despite the plausibility of comparative advantage as a key mechanism in individuals' choice of field, it has been rarely empirically examined (Jonsson, 1999). We therefore contribute to the literature on STEM inequality by examining whether the comparative advantage that males and females possess in different subjects offers a more effective explanation of gender disparities at the postsecondary level.

Finally, this study will also examine trends over time to explore whether accounting for prior achievement contributes differentially to explaining the gender gap of major for different cohorts. A simple extension of underachievement arguments would anticipate that if gaps in prior preparation are larger among earlier cohorts, then a larger share of gender disparities in choice of major will be explained. Yet a consideration of changes in the higher education landscape offers a more complex picture. Rates of college attendance and attainment have increased steadily for both genders over the past several decades, but historical gender patterns have reversed such that women have gained the advantage (Buchmann & DiPrete, 2006). Neo-institutionalist theories of social change would argue that in addition to the decrease in obstacles to women's presence in higher education and the labor force (Long & Fox, 1995; Ramirez & Wotipka, 2001), we should also see a move toward gender desegregation as a consequence of increasing egalitarianism and the delegitimation of ascribed inequalities, including gender (Barone, 2011; Charles & Bradley, 2002). Although the female share of intended as well as attained bachelor's degrees in physical science and engineering fields has remained relatively flat since the early 1980s (England & Li, 2006), it is nevertheless plausible that such fields have become more universalistic over time, such that differences in prior achievement would explain a larger share of gender inequality in college majors among more recent cohorts, with less of a net effect of gender on entry into these fields. While it is beyond the scope of this article to test theories about large-scale social change or stratification, by focusing on inequality across the past several decades we contribute new and important empirical information to such discussions.

Data and Results

We utilize data from three longitudinal studies conducted by the National Center for Educational Statistics: The High School and Beyond: Sophomore Cohort, the National Educational Longitudinal Study of 1988, and the Educational Longitudinal Study of 2002. We use data from student and parent surveys conducted during the students' sophomore year of high school, which was in 1980, 1990, and 2002, respectively, and from follow-up student surveys conducted during their senior year, as well as 2 years after on-time high school graduation. We also utilize information from students' high school transcripts collected by all three studies to construct measures of course-taking and grades, as discussed in the following. We restrict our analyses to all students who enrolled in a 4-year degree-granting institution and reported having declared a major field of study on the student survey administered 2 years post high school (corresponding to 1984 for HS&B students, 1994 for NELS students, and 2006 for ELS students). Missing data are imputed via single imputation.

Our multivariate models include self-reported measures for students' gender and race/ethnicity. Family background indicators include a series of dummy variables to capture the highest level of education obtained by either parent (with high school graduation as the contrast category). To measure family income we recoded the original ordinal indicator in each data set by taking the midpoint of each income category. For the open-ended final category we extrapolate from the next-to-last category using a modified Pareto formula suggested by Hout (2004). Next we converted the dollar values from HS&B and NELS into equivalent dollars for students in the ELS cohort based on the consumer price index (CPI-U) and then divided all values by 10,000 to facilitate presentation. We also include a dichotomous measure of whether the student enrolled in college the fall subsequent to high school graduation (coded 0) or was delayed in enrollment (coded 1). See the Appendix in the online journal for a detailed description of each of these background variables. Next, we discuss our key variables of interest.

Defining High School Achievement

We consider several distinct conceptualizations of math and science achievement in high school. First, we discuss relatively standard measures of high school academic preparation (math and science course-taking, math and science grades, and math achievement tests) and then we discuss measures of high-end achievement as well as our comparative advantage indicator. To construct measures of course-taking we rely on the students' high school transcripts. Based on the thresholds established by prior research as best capturing students' level of coursework (Adelman, 1999), we distinguish among students whose highest level math course was calculus, precalculus or other advanced math (which includes trigonometry and statistics), or Algebra 2 or below (the reference category). Likewise, we distinguish among four levels of science course-taking: physics, Biology 2 or Chemistry 2 (referred to in tables as advanced science), or Chemistry 1 or below (the reference category). We obtained grades from students' high school transcripts and averaged across all math and science courses taken in high school on the traditional 4-point scale. Students' math test scores are available from both 10th and 12th grade. Because we are interested in comparability across the three time points, we standardize each test score (10th- and 12th-grade test) within cohorts and then take the mean of available standardized scores for each student.[6]

Table 1 shows descriptive statistics for each of these achievement measures separately for males and females by cohort. Most gender differences are quite consistent over these three cohorts. Beginning with rates of advanced course-taking, we see that both genders have increased their representation in the highest courses over time. While the female advantage at the penultimate level has grown over time in both subjects, males have a significant advantage in both calculus and physics course-taking at all three time points (although women have shrunk the physics course-taking gap over time). It is important to point out, however, that these differences are in large part a consequence of sample selection. If we expand the sample to look at the population of high school seniors (rather than those seniors who entered college within 2 years of completing high school), males and females are equally likely to take calculus, and while boys remain more likely to take physics among the larger sample (by 7 percentage points), this difference is smaller than observed for our analytic sample of 4-year college matriculates (a difference of 12 percentage points). Therefore, boys who attend college are increasingly selected on high school academic achievement relative to girls, a pattern most pronounced in the ELS cohort.[7]

Returning to Table 1, across cohorts, women hold an advantage in math/science GPA. This advantage fluctuates slightly between one- and two-tenths of a standard deviation. For math test scores (in a standardized version as described previously), men hold a consistent advantage across cohorts. The magnitude of difference is about four-tenths of a standard deviation in the earliest cohort and three-tenths of a standard deviation in the latest cohort.

As we are interested in examining whether achievement at the upper end of the test score distribution is consequential for gender disparities in choice of major, we turn to focus on male and female students' math test score distribution. Across cohorts, we see that men's representation toward the top of the test score distribution is several percentage points higher than women's. For example, in the HS&B cohort, approximately 7% of men ranked in the 90th to 95th percentile of math test takes, compared to approximately 5% of women. The corresponding numbers for ELS are

Table 1

Descriptive Statistics for High School Academic Achievement (for Students Attending 4-Year Colleges Within 2 Years of High School Completion)

	High School Class of 1982 (HS&B)			High School Class of 1992 (NELS)			High School Class of 2004 (ELS)		
	Male Mean	Female Mean	Difference	Male Mean	Female Mean	Difference	Male Mean	Female Mean	Difference
Highest math course taken									
Algebra 2 or below	0.41	0.52***	−0.11	0.28	0.32	−0.04	0.19	0.19	0.00
Precalculus or advanced math	0.44	0.36**	0.08	0.47	0.48	−0.01	0.51	0.58***	−0.07
Calculus	0.15	0.12*	0.03	0.25	0.21*	0.04	0.30	0.23***	0.07
Highest science course taken									
Chemistry or below	0.43	0.65***	−0.22	0.29	0.35***	−0.06	0.22	0.24	−0.02
Advanced science	0.12	0.13	−0.01	0.16	0.25***	−0.09	0.21	0.31***	−0.10
Physics	0.44	0.23***	0.21	0.55	0.40***	0.15	0.57	0.45***	0.12
Math/science GPA	2.65	2.75**	−0.13	2.35	2.44**	−0.12	2.51	2.67***	−0.23
	(0.74)	(0.76)		(0.80)	(0.73)		(0.71)	(0.68)	
Math test score	0.92	0.61***	0.39	0.74	0.61***	0.16	0.69	0.44***	0.30
	(0.79)	(0.82)		(0.82)	(0.77)		(0.82)	(0.78)	
Math test score percentiles									
Less than the 75th percentile	0.65	0.79***	−0.14	0.71	0.79***	−0.08	0.69	0.82***	−0.13
75th to 90th percentile	0.20	0.13***	0.07	0.18	0.14**	0.04	0.17	0.13***	0.04
90th to 95th percentile	0.07	0.05*	0.02	0.05	0.04	0.01	0.07	0.03***	0.04
Above 95th percentile	0.09	0.03***	0.06	0.06	0.03***	0.03	0.07	0.02***	0.05
Comparative advantage measures									
Difference between math/science GPA and English GPA	0.26	0.06***	0.38	−0.04	−0.36***	0.48	−0.08	−0.19***	0.27
	(0.53)	(0.55)		(0.50)	(0.68)		(0.43)	(0.42)	
Difference between math and reading test percentiles	2.98	−1.50***	0.21	4.82	1.97***	0.21	5.13	−4.62***	0.41
	(22.46)	(21.31)		(23.42)	(22.80)		(24.18)	(23.01)	
*N*s (weighted)	1,588	1,702		1,735	2,056		2,149	2,756	

Note. Proportions and means are displayed for males and females, with standard deviations for continuous variables in parentheses.
An asterisk indicates that the male and female means are statistically different (*$p < .05$, **$p < .01$, ***$p < .001$). Differences for proportions are calculated by subtracting the female proportion from the male proportion. Differences for continuous variables are calculated as the difference between the means divided by the pooled standard deviation. HS&B = High School & Beyond; NELS = National Education Longitudinal Study; ELS = Educational Longitudinal Study.

approximately 7% and 3%, respectively. Thus, women are indeed underrepresented toward the elite end of the test score distribution and this does not appear to have diminished over time, at least among students attending college.

Our final consideration of how achievement might pertain to men and women's choice of a STEM major centers on the idea of comparative advantage. Here we compare students' performance in math and science to performance in reading/English by creating measures of the differences for both grades and test scores. To measure comparative advantage for GPA, we simply subtract students' cumulative GPA in English classes taken during high school from their GPA in their math and science courses. For test score differences, we follow the operationalization utilized by Xie and Achen (2009). We rely on the reading tests administered in tandem with the math tests in all three studies and calculate the difference between the students' math test percentile and their reading test percentile. In all of our difference measures, a value greater than 0 indicates a comparative advantage in math/science, while a value less than 0 indicates an advantage in reading/English.[8] We also include variables to capture the number of honors English courses taken during high school as a control variable (see Appendix for full description).

Turning again to Table 1, we see that both male and female college matriculates from the HS&B cohort had a higher math/science GPA than English GPA in high school (as indicated by the positive values on the GPA difference measure). For the NELS and ELS cohorts, students of both genders averaged higher grades in English than in math/science, but this comparative advantage was more pronounced for females than for males. For example, in the ELS cohort, boys' English grades were higher than their math/science grades by about one-tenth of a grade point, while girls' English grades were approximately one-fifth of a grade point higher than their math/science grades. Comparing test scores across subjects, males are on average more proficient in math than reading comprehension across all three cohorts (by 3–5 percentage points). Females are about 2 percentage points more proficient on math than reading comprehension in the NELS cohort, but in both the HS&B and ELS cohorts they scored on average several percentage points higher on the reading than the math test (by approximately 1.5 and 4.5 percentage points, respectively).

Defining College Major

Our outcome of interest is student's declared major. Because different fields within the broad category of STEM are known to have different histories of gender segregation, we distinguish among students who declared a major in PS/E fields (which includes physical sciences, engineering, math, and computer science), those who declared a major in the biological sciences, and those who declared a major in a non-STEM field.

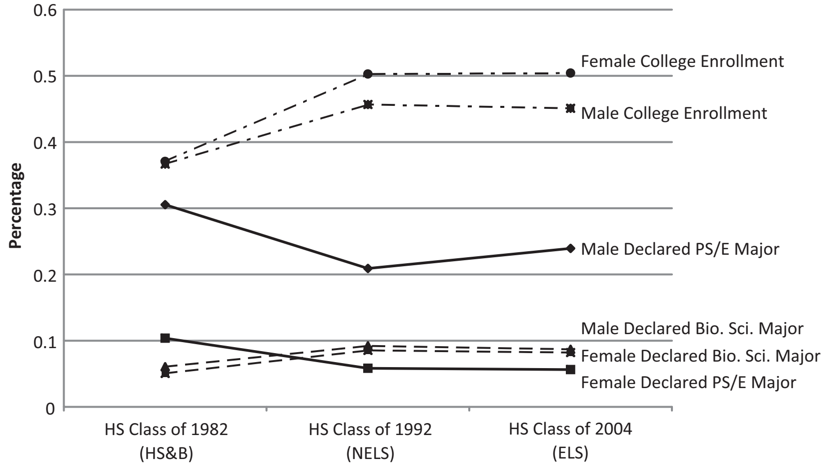

Figure 1. **Rates of college entrance and choice of science, technology, engineering, and mathematics (STEM) major by gender (for Students attending 4-year colleges within 2 years of high school completion).**

Note. PS/E = physical science/engineering; HS&B = High School & Beyond; NELS = National Education Longitudinal Study; ELS = Educational Longitudinal Study.

Figure 1 displays the breakdown of male and female students into these two different categories of STEM majors across the three different national cohorts of college matriculates, as well as trend lines that show the percentages of male and female high school graduates that attend 4-year colleges for each cohort. As noted elsewhere (Ewert, 2010), both genders have increased their rates of college attendance over the time period, yet women have eclipsed men during recent decades. The share of students declaring a major in the field of the biological sciences is generally equitable across all three time points. Approximately 10% of men and women declared a biological science major in both NELS and ELS, with closer to 5% of both genders doing so in HS&B. In contrast, female college students are underrepresented in physical science and engineering fields for all three cohorts. In these fields, there is a male advantage ranging from 15 to 20 percentage points that remains constant despite the fact that there is an overall decrease in the percentage of students majoring in PS/E from the HS&B cohort to the NELS cohort.[9] Given the similar gender patterns in the biological sciences, we subsequently restrict the analyses shown here to those that model the likelihood of students majoring in PS/E fields versus non-STEM fields.

Predicting Choice of Major

We now turn to the results of multivariate analyses. Our goal is to examine the extent to which gender disparities in representation in PS/E fields at the postsecondary level appear to be related to achievement gaps in high school, as well as whether and how such patterns have changed over time. In order to facilitate comparisons across nested models as well as cross-cohort comparisons we present average marginal effects. Unlike odds ratios, average marginal effects are insensitive to differences in unobserved heteroskedasticity across groups or over time (Hoetker, 2007; Mood, 2010). They are also more intuitive, corresponding to the expected change in the probability of the outcome associated with a one-unit change in the predictor, averaged across all observations in the analytic sample.[10]

Results are displayed in Table 2. We begin with a baseline model that includes gender, social class background, and an indicator of delayed college entry. For the HS&B cohort, on average the probability that a male student declares a PS/E major is 21 percentage points greater than that of a female student; the corresponding effect observed for the ELS cohort is approximately 20 percentage points. In the next model we include measures of course-taking, grades, and test scores that are similar to those from some recent research (Riegle-Crumb & King, 2010; Xie & Shauman, 2003); this will provide a basis of comparison for our subsequent analyses modeling achievement at the top of the test distribution as well as comparative advantage.

We see that across the cohorts there is a strong link between high school math and science achievement and the declaration of a PS/E major. Both math/science GPA and physics course-taking significantly predict choice of PS/E major in all three cohorts. For example, in HS&B students who take physics have a 14.6 percentage point higher probability of declaring a PS/E major than those whose highest science course is chemistry or below. The average marginal effect of taking physics decreases across the three data sets to approximately 4 percentage points in ELS. As for math course-taking, calculus is a significant predictor of declaring a PS/E major for both the NELS and ELS cohorts. In ELS, students who take calculus have a 12.9 percentage point higher probability of declaring a PS/E major than students who complete Algebra 2 or less, while in NELS students in calculus have a 9.4 percentage point advantage. For math test score, its predictive power (measured linearly) decreases in both size and statistical significance from HS&B to ELS.

With regard to explaining gender disparities, once we condition on these measures of achievement, the average marginal effect of gender decreases from about 21 percentage points to 16 percentage points for students in the HS&B cohort. The parallel decrease in both NELS and ELS is even smaller; for these later cohorts the decrease is about 2 percentage points. Thus as anticipated, accounting for average test scores and GPA as well as

Table 2

Average Marginal Effects on Probability of Declaring a Physical Science/Engineering (PS/E) Major

	High School Class of 1982 (HS&B)[a]				High School Class of 1992 (NELS)				High School Class of 2004 (ELS)			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Female	−0.215***	−0.159***	−0.157***	−0.137***	−0.170***	−0.146***	−0.143***	−0.123***	−0.196***	−0.181***	−0.174***	−0.155***
	(0.019)	(0.017)	(0.017)	(0.018)	(0.016)	(0.015)	(0.014)	(0.015)	(0.014)	(0.013)	(0.013)	(0.013)
Highest math course												
Precalculus or advanced math		−0.013	−0.012	−0.009		0.013	0.021	0.026		0.030	0.041~	0.043*
		(0.022)	(0.022)	(0.022)		(0.020)	(0.022)	(0.022)		(0.022)	(0.022)	(0.022)
Calculus		0.041	0.036	0.045		0.094***	0.094***	0.099***		0.129***	0.124***	0.124***
		(0.032)	(0.032)	(0.032)		(0.026)	(0.027)	(0.027)		(0.027)	(0.026)	(0.026)
Highest science course												
Advanced science		0.007	0.007	0.011		−0.007	−0.004	−0.002		−0.005	−0.004	-0.000
		(0.030)	(0.030)	(0.031)		(0.025)	(0.025)	(0.025)		(0.020)	(0.020)	(0.020)
Physics		0.146***	0.144***	0.148***		0.062***	0.064***	0.067***		0.044**	0.044**	0.045**
		(0.020)	(0.020)	(0.020)		(0.017)	(0.017)	(0.017)		(0.017)	(0.016)	(0.016)
Math/science GPA		0.068***	0.066***	0.047**		0.033**	0.029*	0.008		0.044***	0.042***	0.029*
		(0.014)	(0.014)	(0.015)		(0.012)	(0.012)	(0.013)		(0.012)	(0.012)	(0.013)
Math test score		0.066***				0.048***				0.015		
		(0.016)				(0.014)				(0.011)		
Spline models												
Math test score below 75th percentile			0.002**	0.002**			0.001	0.001			-0.000	-0.001
			(0.001)	(0.001)			(0.000)	(0.000)			(0.000)	(0.000)
Math test score above 75th percentile			0.003*	0.003*			0.003**	0.003**			0.004***	0.004***
			(0.001)	(0.001)			(0.001)	(0.001)			(0.001)	(0.001)

(continued)

Table 2 **(continued)**

	High School Class of 1982 (HS&B)[a]				High School Class of 1992 (NELS)				High School Class of 2004 (ELS)			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Comparative advantage												
Difference between math/science GPA and English GPA				0.059***				0.069***				0.058***
				(0.017)				(0.015)				(0.018)
Difference between math and reading test percentiles				0.001				0.000				0.001***
				(0.000)				(0.000)				(0.000)
Racial/ethnic group												
Black	−0.003	0.132***	0.124***	0.113***	0.054*	0.122***	0.113***	0.109***	0.036~	0.107***	0.098***	0.087***
	(0.032)	(0.030)	(0.029)	(0.029)	(0.026)	(0.024)	(0.023)	(0.024)	(0.020)	(0.021)	(0.021)	(0.020)
Hispanic	0.048	0.116**	0.114**	0.112**	−0.002	0.027	0.028	0.026	0.000	0.026	0.024	0.027
	(0.037)	(0.038)	(0.038)	(0.037)	(0.030)	(0.030)	(0.030)	(0.028)	(0.024)	(0.024)	(0.023)	(0.022)
Asian	0.106*	0.039	0.039	0.035	0.039	0.004	0.002	0.002	0.060**	0.027	0.024	0.017
	(0.045)	(0.046)	(0.046)	(0.043)	(0.028)	(0.020)	(0.020)	(0.020)	(0.018)	(0.018)	(0.018)	(0.018)
Parent's highest level of education												
No high school diploma	0.027	0.033	0.035	0.035	−0.022	0.033	0.026	0.017	−0.006	0.006	−0.004	−0.015
	(0.047)	(0.042)	(0.042)	(0.042)	(0.040)	(0.037)	(0.036)	(0.036)	(0.045)	(0.047)	(0.046)	(0.045)
Attended some college, no bachelor's degree	−0.006	−0.010	−0.009	−0.010	−0.033*	−0.009	−0.008	−0.011	−0.020	−0.022	−0.022	−0.021
	(0.043)	(0.037)	(0.037)	(0.037)	(0.017)	(0.016)	(0.016)	(0.016)	(0.023)	(0.022)	(0.022)	(0.022)
Bachelor's degree	0.002	−0.021	−0.019	−0.018	−0.024	−0.015	−0.016	−0.019	0.009	−0.020	−0.020	−0.013
	(0.048)	(0.042)	(0.042)	(0.042)	(0.019)	(0.017)	(0.017)	(0.017)	(0.023)	(0.022)	(0.022)	(0.022)
Advanced degree	−0.027	−0.061	−0.062	−0.063	0.001	−0.010	−0.014	−0.013	0.023	−0.020	−0.023	−0.013
	(0.052)	(0.046)	(0.046)	(0.046)	(0.034)	(0.029)	(0.029)	(0.028)	(0.023)	(0.023)	(0.023)	(0.023)

(continued)

Table 2 **(continued)**

	High School Class of 1982 (HS&B)[a]				High School Class of 1992 (NELS)				High School Class of 2004 (ELS)			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Family income	−0.004	−0.005*	−0.005*	−0.005*	−0.003**	−0.004***	−0.005***	−0.004***	−0.001	−0.002*	−0.002*	−0.002*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Delayed start of college	0.071	0.244**	0.234**	0.222*	−0.162**	−0.001	−0.096	−0.097	−0.068	−0.000	−0.003	−0.016
	(0.102)	(0.087)	(0.087)	(0.088)	(0.057)	(0.059)	(0.058)	(0.058)	(0.041)	(0.038)	(0.038)	(0.038)
English course-taking												
One-half to two honors or AP/IB English courses				−0.049				−0.014				−0.011
				(0.026)				(0.016)				(0.015)
More than two honors or AP/IB English courses				−0.043				−0.015				−0.020
				(0.038)				(0.017)				(0.016)
N	3,115				3,435				4477			

Note. HS&B = High School & Beyond; NELS = National Education Longitudinal Study; ELS = Educational Longitudinal Study. Reference categories are as follows: Algebra 2 or below (for highest math course), Chemistry or below (for highest science course), non-Hispanic white (for Racial/Ethnic group), high school graduate (for parent education level), and no honors or AP/IB (for English course-taking)..

[a]For each of the three cohorts the sample is limited to those students who attend a 4-year institution and declared a major within 2 years of high school graduation.

$*p < .05$; $**p < .01$; $***p < .001$.

advanced course-taking does very little to explain the gender disparity in entrance into PS/E majors.[11]

The results of models focusing on the upper end of the math test score distribution are shown in Model 3 for each cohort in Table 2. The linear measure used in Model 2 does not allow for different slopes across the achievement distribution, and as discussed earlier, it could be that achievement at the high end plays a bigger role in explaining gender disparities in choice of major. While previous research has suggested that the very elite segment of the test score distribution, namely, the top 5% or 10%, is perhaps the most consequential (Penner & Paret, 2008; Robinson & Lubienski, 2011; Xie & Shauman, 2003), these cut-offs seem quite restrictive as well as somewhat arbitrary. We explore the underlying relationship between test scores and choice of major by graphing the share of men and women declaring a PS/E major for each percentile of the test score distribution (see the Appendix for the plots). The plots suggest that the probability of declaring a PS/E major is random with respect to test scores for students below about the third quartile of the test score distribution, at least for the latter two cohorts, but linear with respect to test scores above the third quartile. Based on these graphs, we operationalize test score as a linear spline with a single knot at the 75th percentile.[12]

Turning our attention back to Model 3 in Table 2, for HS&B it appears that both splines are roughly equivalent conditional on other attributes, while for the two later cohorts only the spline capturing the top 25% is greater than zero and statistically significant. Thus for NELS and ELS, test score is only predictive of choice of PS/E major among the top 25% of students. As observed in Table 1, women in all cohorts are underrepresented in this top quartile. Yet when examining the average marginal effect of gender, modeling test score in this manner leaves the effect virtually unaltered from Model 2. As such, it seems that gender differences in choice of PS/E major are constant across the test score distribution, and therefore adding measures that more explicitly model the high end do not help to further explain the gap.

Finally, we consider whether comparative advantage indicators might shed more light on gender disparities in choice of PS/E major than previous models utilizing absolute indicators of achievement. In Model 4 of Table 2 we add measures of the difference between students' GPA and test scores in math/science versus English/reading (note that we retain the measurement of test score in splines as it is the preferred operationalization). Students who earn better grades in math/science than in English are significantly more likely to declare a PS/E major at all three time points. For example, on average students in NELS who have a 3.5 math/science GPA and a 2.5 English GPA have a 6.9 percentage point higher probability of declaring a physical science/engineering major compared to students who have a 3.5 GPA in all subjects.

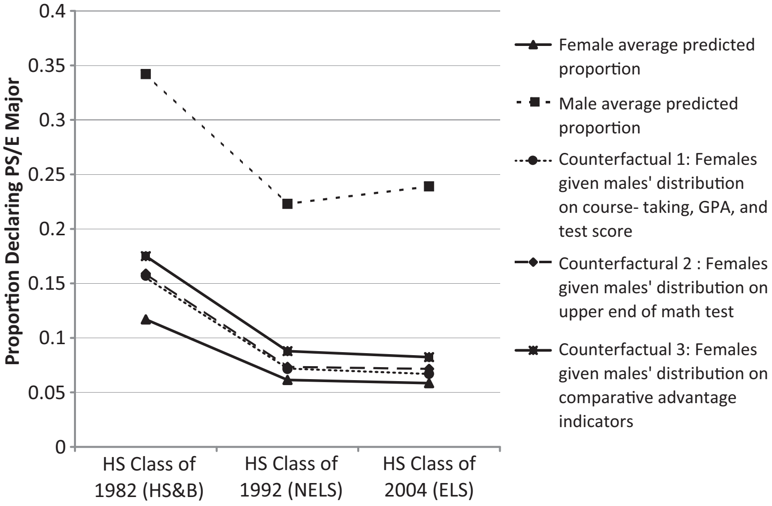

Figure 2. **Predicted and counterfactual proportions for declaring a physical science/engineering major.**

Note. PS/E = physical science/engineering; HS&B = High School & Beyond; NELS = National Education Longitudinal Study; ELS = Educational Longitudinal Study.

In examining how the inclusion of these measures of comparative advantage changes the average marginal effect of gender, we note that there is a small reduction of about 2 percentage points for all three cohorts. For example, the average marginal effect in HS&B decreases from almost 16 percentage points to about 14 percentage points, while for ELS it decreases from 18 to slightly less than 16 points. Interestingly, supplementary analyses including each comparative advantage indicator separately reveal that it is the inclusion of the GPA measure that is primarily responsible for this modest reduction. It is not boys' comparative advantage in math test scores over reading test scores that works to chip away a little at the gender gap in choice of major, but rather girls' comparative advantage in English grades relative to math/science grades. The coefficient for comparative advantage in test scores is very small in magnitude and statistically significant only for the ELS cohort.[13]

To help summarize the results of our analyses and more easily focus on comparing patterns across the decades, in Figure 2 we show results of a counterfactual analyses showing the gap in PS/E majors that we would expect to see if women had men's high school achievement. The dark solid line on the bottom shows the average predicted proportion of women in PS/E majors over time (net of controls for social background) and the top dashed line shows the same for men. We then include three additional lines that show the counterfactual of how women would look if they had men's distribution on achievement, with one line corresponding to each of the Models 2 through 4 in Table 2. As can be seen in Figure 2, the line representing the counterfactual of the proportion of women in PS/E we would expect to see if they had men's scores on the comparative advantage variables slightly improves upon the other models, such that it explains a little more of the gender gap in PS/E majors. However, it is clear that accounting for achievement, however measured, does very little to help explain gender gap in PS/E major over time.

Finally, turning back to Table 2, there are a few effects of other variables on choice of PS/E major that we find worth noting. Across all three cohorts, Black students have a higher probability of declaring a PS/E major than White students conditional on academic achievement. A similar pattern applies to Hispanic youth in HS&B only; in the later two cohorts there is not a statistically significant difference in the likelihood of declaring a PS/E major between White and Hispanic students. Students from homes characterized by higher levels of parental education do not differ from their peers from less educated homes in terms of declaring a PS/E major. We find a significant effect for income, but it goes in a direction opposite to what might be expected: Each additional $10,000 in real family income is associated with a slight decrease (between 0.2 and 0.5 percentage points depending on the cohort) in the probability of declaring a physical science/engineering major.

Conclusion

This article investigated the empirical basis for often-repeated arguments that gender differences in entrance into STEM postsecondary majors are largely explained by disparities in prior academic achievement. We contributed to the relatively small body of empirical work on this topic using national-level data by considering several different conceptualizations of high school achievement that might be relevant for gender inequalities at the college level. Our results indicate that whether focusing on the high end of the test distribution or focusing more broadly on average differences across several indicators including course-taking, conditioning on achievement does extremely little to diminish the gender gap in PS/E majors across time. While models that include measures of comparative advantage in math/science (vs. English/reading) appear to account for more of the gender gap in field of study than the other models considered, overall the evidence we present strongly undermines the assertion that women's underrepresentation in PS/E fields is due to deficits in prior achievement.

These results are important given the prevalence of this assertion in the literature on gender inequality in STEM areas, particularly among those offering a rationale for why we should be concerned about the test score gap observed at earlier stages of the life course (Fryer & Levitt, 2009; Good et al., 2007; Muller et al., 2001; Penner & Paret, 2008; Wai et al., 2010). As noted earlier, gender gaps do remain on many national standardized tests. We are not suggesting that such disparities are unimportant; however, we argue that researchers studying them need to provide another reason why they are important. Continuing to suggest such gaps are an important cause of women's underrepresentation in some STEM fields is not only inaccurate but potentially harmful in its consequences if it contributes to the perpetuations of gender stereotypes.

Our analyses also revealed that among our analytic sample of college matriculates, students whose race and social class background are typically associated with educational disadvantages (including Black and lower socioeconomic status youth) were not underrepresented in PS/E majors at any time point. This offers some evidence consistent with the assertion that STEM fields are universalistic, such that social background characteristics per se are irrelevant for entry (Merton, 1973; Xie & Achen, 2009). Yet these patterns also serve to place the gender trends observed here in even starker relief. Why is gender the indicator of ascribed identity that continues to strongly differentiate entrance into PS/E fields of study net of achievement differences?

We think that considering inequality in STEM through the lens of sociological theories that recognize gender as a social structure are more likely to help answer this question than those that focus on differences in individual skills as tested here. Critical gender theorists posit that gender is a multitiered system with connections between three levels: the larger macro level of politics, economics, and culture; the more micro contexts of personal interactions and exchanges; and lastly, the individual with internalized beliefs and values (Eisenhart & Finkel, 1998; England, 2010; Risman, 2004). This implies that we should think further about how STEM fields fit within the broader structure of gender inequality rather than focusing on such fields in exclusion. Consistent with this view, Charles and Bradley (2002) argue that the U.S. culture (as well as those of many Western nations) still strongly endorses the idea that the genders are innately and fundamentally "equal but different," and therefore continues to encourage the enactment of distinct affinities, distinguishing between those that are appropriately feminine or masculine. England (2010) also argues that our cultural and institutional logics include the maintenance of gender essentialist beliefs, noting that a large part of women's progress in the educational and occupational sectors is in domains that do not violate traditional gender roles; and even when they do enter male-typical domains, women are more likely to choose those subfields within them that seem "consistent with their (tacitly gendered) notions of their interests and their 'true selves'" (p. 161). From this perspective, girls may improve their math and science achievement in secondary school, take more advanced courses, and excel in those courses because such measures of performance are generally important for college matriculation, independent of field of study (Adelman, 1999). Yet because of the societal pervasiveness of gender essentialist beliefs and the accompanying socialization and micro-level interactions that support them, gendered patterns in choice of major will not shift accordingly.

Several gender theorists point to the level of interactions and exchanges as perhaps the least studied and most potentially informative area of research on gender inequality (Deutsch, 2007; Ridgeway, 1997; Risman, 2004). Such a lens also prompts us to move beyond a treatment of individual characteristics as fixed or exogenous; rather, we should think of gender as a role or identity that is likely more salient in certain social interactions or contexts than in others, with resultant implications for the activation of stereotypes and social scripts (Ridgeway & Correll, 2004). For example, future research might examine whether gender appears to be less relevant in social interactions among students, or between students and their teachers, in high school biology classes as compared to physics classes. Given the early formation of career and subject interests, additional insights might be provided by focusing on interactions within math and science classrooms at the elementary or middle school level from a similar perspective. Comparing these different micro-level contexts might provide more information about when, where, and how particular scientific identities are cultivated or dampened and subsequently why females might remain less likely to enter some postsecondary STEM fields of study *despite* comparable levels of achievement to their male peers.

Finally, consistent with research by Eccles (1994) on how individual preferences are shaped by both interests and feelings of efficacy, future research should focus more on thinking about the choices women make as a choice *for* something rather than simply a choice *against* PS/E fields (Stinebrickner & Stinebrickener, 2011; Zafar, 2011). What do many qualified females find more attractive in these other fields of study, and more importantly why? In answering such questions we should think more critically about the social structures that shape and scaffold the development of preferences and the dynamic rather than static nature of such preferences. We must also consider variation both within and across genders, for example, by examining why and how some females resist cultural expectations and pursue degrees in engineering. By doing so we recognize the importance of human agency and the potential for gender to be "undone," or perhaps reconstructed using alternative definitions of both the nature of STEM disciplines as well as gender as a social category (Deutsch, 2007; Eisenhart & Finkel, 1998).

The primary aim of this article was to test the applicability of an old explanation for inequality that continues to resonate. We have offered powerful evidence that long-standing underachievement arguments fail to provide the answer to the question of gender inequality in representation in STEM postsecondary fields. We are unable to test or prove the validity of alternative answers with existing national surveys. A combination of future surveys and qualitative studies designed specifically to address some of the macro-level sociological processes discussed here as well as the more micro-level social-psychological ones are likely necessary to more effectively answer this elusive question.

Notes

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[1]It is important to note that recent research finds that women do not leave science, technology, engineering, and math (STEM) majors at higher rates than men; contingent on entering a STEM major, women and men have the same attrition rates (Xie & Shauman, 2003). Therefore the crucial threshold for examining gender disparities is the entrance into the major, which is what we model here.

[2]For example, early work by Ware, Steckler, and Leserman (1985); Oakes (1990); and Maple and Stage (1991) found that math SAT score and math and science grades and high school course-taking were among the strongest predictors of choice of a STEM major. More recent analyses by Xie and Shauman (2003) and Crisp, Nora, and Taggart (2009) concur with these findings.

[3]The disagreement about the source of females' lower achievement is the result of a continued debate about the extent to which innate and biological differences in ability are the culprit or whether sociocultural forces work to produce differences. See Blickenstaff (2005) or Halpern et al. (2007) for a review of the related arguments and supporting evidence.

[4]Indeed the two studies discussed previously acknowledge the small magnitude of the gender gap they examine. Fryer and Levitt (2009), for example, find a difference of about .2 standard deviations at the end of fifth grade, while Robinson and Lubienski (2010) note a gap of .12 standard deviations at the end of eighth grade.

[5]Based on this assumption, several studies have chosen to limit their exploration of gender equality in STEM fields to students with high levels of achievement. See for example, Boli, Allen, and Payne (1985) as well as Seymour and Hewitt (1997), who limited their study to students scoring highly on the math SAT.

[6]Standardizing test scores within cohorts discards information about absolute levels of knowledge that may increase or decline across cohorts. Models using the original IRT (item response theory) metrics and those using SAT math scores in lieu of National Center of Education Statistics (NCES) standardized scores produced substantively identical results to those presented here, as are models that include science test scores available only for the High School & Beyond (HS&B) and National Education Longitudinal Study (NELS) cohorts.

[7]Results are available upon request from the authors. This pattern appears to be consistent with findings by Buchmann and DiPrete (2006), as well as Ewert (2010), who find gender differences in the selection into college as a function of students' background.

[8]We also created ratio versions of students' comparative advantage in GPA and test scores; results of analyses were substantively identical to those presented here.

[9]Data from the National Science Foundation (NSF) show a similar pattern of decline for the same time period in physical science/engineering (PS/E) degree attainment among both males and females (National Science Board, 2008).

[10]Models with odds ratios provide substantively similar results with regard to gender patterns. Results available upon request.

[11]We tested for but did not find any evidence of significant interactions between gender and any of our achievement indicators across models and cohorts.

[12]To ensure that we specified the best model we also experimented with placing additional knots at the 85th and 95th percentiles. However, Bayesian Information Criterion (BIC) statistics favored the model with only one knot, where test score is captured by two different terms, one measuring the relationship between test score and choice of major for those who are lower than the 75th percentile for test scores and

one for those higher than the 75th percentile. This model was also a better fit than the single linear term used in Model 2 (particularly for the Educational Longitudinal Study [ELS] cohort). We also examined the best functional form for the relationship between GPA and choice of major (although we note that focusing on the higher ends of the GPA distribution would not better explain gender disparities in choice of major since female students trump /male students on that measure). Looking first at scatterplots parallel to those created for test scores, we observed that the relationship appeared to be quite linear; subsequent spline models placing knots at various points in the GPA distribution did nothing to improve model fit. Therefore we retain a simple linear measure of GPA.

[13]In results not shown (available upon request) we examined the possibility that it is students at the top end of the test score distribution that respond most to their comparative advantage by including interaction terms between those in the top 25% of test scorers and each of the comparative advantage indictors. None were significant and neither did their inclusion improve model fit.

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