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The puzzle of missing female engineers: Academic preparation, ability beliefs, and preferences

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ABSTRACT

This paper uses administrative North Carolina data linked from high school to college and national surveys to characterize the largest contributor to the STEM gender gap: engineering. Disparities are the result of differential entry during high school or earlier rather than postsecondary exit. Differences in pre-college academic preparation account for 5 to 7% of the gap. Females' relative lack of academic self-confidence explains 8%, while other-regarding preferences and professional goals capture a further 14%. Empirical evidence using identifying variation in the gender composition of twins in North Carolina shows that opposite-sex pairs are more likely to pursue gender-stereotypical majors.

1. Introduction

The past several decades bore witness to significant changes in education-related gender gaps. In the years immediately following World War II, only one female enrolled in college for every 2.3 males. Yet by the 1980s, women surpassed men in both college enrollment and completion (Goldin, Katz, & Kuziemko, 2006). These successes in postsecondary educational attainment, however, failed to translate into higher rates of female participation in select science, technology, engineering and math (STEM) fields, where women are still vastly underrepresented (Griffith, 2010; Turner & Bowen, 1999). Gender disparities are most glaring in the subfield of engineering, where women comprise only 12% of working engineers in 2013 (Corbett, 2015; Legewie & DiPrete, 2014). The persistence of the sizable engineering disparity in spite of gender gap reversals in subjects such as biology is a prevailing puzzle.

Gender disparities in fields of study have lasting consequences for longer-term earnings and skill distributions. STEM graduates enjoy a substantial pay premium relative to peers in other fields. The difference in log wages between engineers and education majors, for instance, rivals the earnings gap between college and high school graduates (Altonji, Blom, & Meghir, 2012). Differential take-up of science and math-intensive fields accounts for a notable share of the male-female earnings gap, such that achieving gender parity on major choice could significantly reduce earnings inequality (Blau & Kahn, 2000; Brown & Corcoran, 1997; Paglin & Rufolo, 1990). Gender gaps in major or occupational choice can also lead to differential accumulation of STEM-focused human capital among men and women that matter for tomorrow's workforce.

This paper uses new administrative data from North Carolina and a pooled national survey of college freshmen to investigate the largest contributor to STEM disparities: engineering. While a plethora of economics studies focuses on the aggregate STEM gender gap, comparatively little research examines specific STEM subfields. Yet the divergent patterns by subfield, from postsecondary gender parity in biology to striking gaps in computer science and engineering, necessitate a more targeted approach. This work contributes evidence on the gender gap along three dimensions. The first is to document the size of the disparity in engineering and its evolution from the beginning of high school through postsecondary schooling. Linked administrative data permits a detailed look at how major orientation in high school translates to actual major choice during the critical transition to college. Second, I differentiate between the roles of entry versus exit during college, using administrative postsecondary data to document attrition rates by gender. The final and most substantial component examines contributors to the gender gap, ranging from individuals' ability beliefs to professional preferences. The combination of a statewide longitudinal dataset and national survey data enables a more comprehensive account of factors underlying the engineering gender gap than previously available.

The datasets' temporal coverage permits a closer look at engineering participation starting in high school. Using engineering orientation or choice as outcome variables, I document a disparity of over 8 percentage points in 9th grade and 11 percentage points after the first year of postsecondary education. The magnitude of this gap is especially striking in light of baseline female engineering participation rates

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between 2 to 4%. Longitudinal data in North Carolina shows that while the majority of the postsecondary gender gap is explained by high school engineering orientation, women are nevertheless less likely to convert early interest in engineering to actual major choice. Once students have declared an engineering major in the North Carolina public university system, I find no evidence to support systematically higher attrition among female students. Results indicate that the gap is mainly attributable to lower entry among female students rather than higher exit during this period. Efforts to increase the rate of female entry and reduce gender divergence in STEM orientation, in particular engineering, should begin no later than high school and not neglect the crucial transition into college.

Tailored policies rely on a better understanding of the gender gap's contributors. I investigate four explanatory accounts: differences in academic preparation, differences in academic ability beliefs, differences in prosocial values and professional goals, and the role of family structure and gender-based norms. Decomposition evidence shows that SAT scores and high school GPA account for between 5 to 7% of the overall disparity. Course-taking patterns in the first half of high school betray few clues on eventual major orientation. Meanwhile, beliefs about lower academic ability dissuade women from entering the field even after controlling for academic performance. Elevating women to the same belief levels as their male counterparts would bridge the gender gap by 8%. Female preferences for prosocial responsibilities and contributing to the arts over sciences explain over 14% of the gap. Notably, decomposition results for the full sample disguise substantial heterogeneity across racial groups and baseline math ability. Explanatory factors collectively explain more of the gender gap for white, Hispanic, and Asian students than African American students because black females track their male peers more closely in academic preparation and professional goals. The importance of ability beliefs and professional goals is also increasing in baseline math ability. Overcoming the female math confidence deficit alone would bridge the gender gap by 7% among students most academically prepared to enter engineering, relative to 4–5% among lower-scoring students.

Complementing these explanatory accounts is a set of gender-specific norms and expectations conveyed mainly in the family context by parents. To better understand their influence on STEM participation, I use a sample of twin pairs in North Carolina under the identifying assumption that sex assignment is exogenous. A potential challenge to this assumption is the inability to distinguish identical twins from fraternal twins in the data. As such, interpretation depends on how unobserved genetic or environmental factors affecting the presence of identical twins might be correlated with future parental expectations and investments. I find that males from opposite-sex pairs are substantially more likely than males from same-sex pairs to choose engineering as a preferred major. These results cannot be explained by differential math ability or a relative advantage story, in which STEM is chosen by the twin with higher math performance. The specialization along gender-stereotypical lines suggests that gender roles and expectations can play a meaningful role, for instance by encouraging boys to invest in more male-dominated pursuits such as computer skills and engineering.

This paper is organized as follows. The next section highlights engineering's contribution to the overall STEM gap and grounds this study in related literature. Section 3 details the three main administrative and cross-sectional datasets used for decomposition. Section 4 describes the role of entry vs. exit, while the subsequent section outlines the empirical strategy. Section 6 presents evidence on the relevance of each explanatory account. I conclude with a discussion of implications.

2. Factors contributing to the STEM gender gap

Gender gaps in major choice are large and persistent in the US context. Table 1 uses Census data to document the share of recent college graduates across all STEM subjects and by subfield.[1] Although males are twice as likely to graduate from college with a STEM degree on aggregate, this result disguises large variations by subfield. Degree attainment in biology nears gender parity, while fields such as engineering and computer science still exhibit sizable gaps. 11.7% of male graduates select engineering, compared to only 2.5% of females.[2] Over 9 percentage points of the 16 percentage point STEM gap are attributable to gender disparities in engineering, while computer science contributes an additional 4 percentage points. Since engineering plays an outsized role in informing the STEM gender gap, it is the central focus of this paper.

In decomposing the gender gap into explanatory accounts, I draw upon a wealth of literature exploring cross-gender differences in the STEM context. Previous research concentrates on several sources of disparity: academic skills and preparation, family background and expectations, tastes or preferences such as those related to pecuniary payoffs or the work environment, and psychosocial attributes such as ability beliefs. Within academic preparation, the preponderance of research focuses on math skills. Earlier studies often cite differences, although gaps in performance have closed in recent years (Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Xie & Shauman, 2003). Recent studies find small or insignificant gender differences in math standardized tests across elementary and secondary schools (Hyde et al., 2008; Hyde & Mertz, 2009; Sass, 2015), while others show that gaps only materialize several years into school entry (Fryer & Levitt, 2010). Among the mathematically gifted, evidence for higher variability among males shows diminishing gaps over time.[3] Conditioning on performance and grades still leaves a large unexplained residual in the STEM gender gap, suggesting that academic preparation plays a relatively minor role (Card & Payne, 2017; DiPrete & Buchmann, 2013; Turner & Bowen, 1999).

Family background is another potential source of influence on individuals' STEM orientation. Parental expectations of children's math and science abilities and academic trajectories may differ by child's gender, thereby affecting students' investments in such skills (Eccles, Jacobs, & Harold, 1990). These expectations can be shaped by parents' own educational and occupational experiences. While a growing body of literature is formally incorporating parental beliefs as an input into human capital production, limited empirical evidence exists on the role of parental influence for STEM orientation (Agostinelli & Wiswall, 2016; Fryer & Levitt, 2010).

Pre-labor market skill accumulation also depends on individual preferences for field or job attributes. Women may enjoy taking non-STEM courses and sort into those fields on the basis of non-pecuniary factors. Over time, differences across gender preferences can lead to clearly differentiated human capital acquisition. There is growing evidence affirming the important role of preferences. Zafar (2013), for instance, finds that differences in coursework and workplace enjoyment and gaining parents' approval are the primary explanations of divergent major choices among male and female college students.[4]

[1] I define a field as STEM if it belongs to one of the following categories: 1) Agriculture, 2) Computer and Information Sciences, 3) Engineering, 4) Engineering Technologies, 5) Biology and Life Sciences, 6) Mathematics and Statistics, 7) Physical Sciences, and 8) Nuclear, Industrial Radiology, and Biological Technologies, abbreviated as Science Tech.

[2] While this study focuses on the US context, its findings are consistent with gender disparities documented in other countries. For instance, Card and Payne (2017) find a 13.2 percentage point gender difference in engineering participation among Canadian workers between the ages of 25 and 34.

[3] A 13:1 ratio of men to women among high SAT math achievers in the early 1980s has since bridged to approximately 2:1 at the top end of the distribution (Benbow & Stanley, 1983; Ellison & Swanson, 2010).

[4] An important question beyond the scope of this paper is how these preferences develop and evolve over the life course. Evidence shows that environmental factors such as academic context matter. Attending single-sex schools or classrooms with higher shares of females can encourage more women to choose STEM majors (Billger, 2002; Favara, 2012; Solnick, 1995). Similarly, exposure to female teachers and faculty can increase female students' participation in STEM courses and majors (Bettinger & Long, 2005; Carrell, Page, & West, 2010; Dee, 2007; Rothstein, 1995), although some studies find non-existent