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Institutional Context Matters: Linking Characteristics of Universities to the Gender Composition of Engineering and Computer Science Programs

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Abstract

Our research focuses on assessing how institutional factors shape the gendered composition of engineering and computer science degrees. We use data from the Integrated Postsecondary Education Data System (IPEDS) to identify how institutional-level (rather than individual-level) parameters shape this outcome. The IPEDS is an annual survey of all U.S. postsecondary educational institutions and contains data on institutional characteristics such as student body diversity (e.g., race/ethnicity), institutional selectivity (e.g., SAT, Pell grant recipients), Carnegie research classifications, student-to-faculty ratio and institutional size. We analyze completion rates by gender for a sample of four-year institutions (N=525), specifically those with more than 5,000 students awarding degrees in at least one of 19 computer science and engineering programs. Our sample mirrors widely reported national-level trends: Women comprise approximately 16 percent of degree earners in computer science and 18 percent in engineering programs. Because our outcome variables are measured as proportions, we use ordinary least squares (multivariate) regression and employ multiple imputation using chained equations (MICE) to account for missing data. Analyses show that institutional characteristics are associated with gendered completion rates in both fields. In computer science, a higher student-to-faculty ratio is associated with completion rates that exacerbate the underrepresentation of women, whereas HBCU's and institutions with a higher proportion of African American students play a key role in boosting the representation of women in computer science. In contrast, for engineering programs, we find that private and highly selective institutions exacerbate the underrepresentation of women. For both fields, the proportion of Hispanic students is associated with boosting the representation of women, whereas women remain particularly underrepresented at institutions with a higher proportion of Pell-grant funded students. We situate this combination of findings in extant research suggesting that postsecondary educational institutions (or at least the computer science and engineering units) constitute an example of gendered organizations. We then discuss seemingly unintended consequences of diversity and inclusion efforts and outline potential implications for STEM recruitment and retention, in an effort to inform meaningful interventions that can advance women's representation in these two male-dominated fields. We conclude with suggestions for future research.

Introduction

Despite decades of efforts to broaden participation in science, technology, engineering and math (STEM) fields, most professionals in these generally high-paying, high-status occupations continue to be white men. In the United States, the STEM job-growth rate overall is more than twice the average rate for the total workforce [1, p. 201], with most job openings in computer science and engineering (CS&E) [2]. The limited representation of women in these fields is apparent: Women comprise just 28 percent of workers in science and engineering fields overall, and even less in CS&E fields [3].

These labor-force dynamics also reflect trends in U.S. higher education: Although women's postsecondary attainment rates exceed men's, women remain underrepresented in many STEM fields, particularly in CS&E [4]. This constitutes a stark reversal of historical patterns, as computer programming began as a female-dominated field in the 1950s. Though seventy-five percent of the U.S. STEM workforce now hold bachelor's degrees in CS&E fields [3], women remain underrepresented: Between 2000 and 2015, the proportion of women earning CS degrees plunged to somewhere between 16 and 18 percent [5], [6]. Moreover, women currently comprise just 21 percent of engineering bachelor's degrees [7], while Black and Latina women comprise a mere 4 percent of computer science professionals and less than 2 percent of engineers [8]

Most extant research has sought to explain these persistent patterns by focusing on how individual-level factors shape degree patterns [9], [10], [11], [12]. Yet, theoretical and empirical research on organizations also tells us that institutional dynamics matter: Institutional parameters limit access to specific STEM majors, as only a subset of institutions offers CS&E degrees [13], [14]. Moreover, institutions generally reify and reproduce group-level gender and racial inequalities in educational and career trajectories [8], [15], [16], [17], [18], [19]. Indeed, racialized and gendered dynamics shape the types of postsecondary institutions students attend: Women are concentrated in smaller, less selective 4-year and 2-year institutions, while students of color disproportionately earn degrees at HBCUs/HSIs [20], [21], [22]. Thus, many federal agencies have incentivized efforts to broaden STEM participation at the institutional level (e.g., NSF's ADVANCE and INCLUDES initiatives). To date, such efforts have met varying success [23].

To advance our understanding of which specific institutional characteristics are associated with the sex composition of STEM degrees earned, we use 2015 data from the Integrated Postsecondary Education Data System (IPEDS). Note that our main objective is to assess how institutional factors explain degree-earning patterns at the institutional-level (rather than graduation rates, which connote individual-level odds of earning a degree). Because of the significant disruption created by the COVID19 pandemic, we selected the most recent wave unaffected by the pandemic, as students attending in 2015 most likely finished before the onset of the pandemic.

Specifically, we focus on the proportion of degrees in Computer Science and Engineering (CS&E) earned by women. Our study answers recent calls by scholars such as Correll [17], and Fox et al. [13], to identify specific post-secondary institutional characteristics that may contribute to social inequalities in particular STEM disciplines. We also build on [24], [25] recent studies of how institutional dynamics shape both academic and non-academic trajectories at postsecondary institutions [25].

We ask: To what extent can institutional factors explain differences in the overall proportion of CS&E degrees earned by women? To what extent do these institutional factors differ for computer science vs. engineering? We examine four "clusters" of institutional factors: institutional-type characteristics, institutional demographics, institutional selectivity, and ecological/contextual factors.

Background

Most research examining gender disparities in STEM trajectories engages concepts and explanations grounded in individual-level factors. While unquestionably important, we summarize this research briefly here. In essence, most explanations for persistent gender gaps and disparities emphasize motivation, ability, and background characteristics, selection and exposure dynamics, or interactions with families, teachers, and peers. Others stress how external and cultural constraints -- or "preferences all things considered" in Mann & DiPrete's terms (2013) -- come into play, as well as marginalization dynamics related to "glass ceilings," "hostile climate," and stereotype threat [11], [16], [18], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39].

Our approach differs: We examine *institutional-level* outcomes. We ground our analyses in the recognition that -- no matter how outwardly egalitarian -- inequalities persist in most organizations, including postsecondary institutions. We build on the concept of gendered organizations initially developed by and associates to explain workplace dynamics [13], [15], [16], [19], [40], [41] and additional research that has demonstrated the utility of this concept with respect to postsecondary institutions. We know comparatively little about which specific characteristics of postsecondary institutions are associated with women's representation in STEM fields overall (but see [13], [26]), never mind specific STEM fields, such as CS&E. Our approach is also informed by Fox et al.'s [13] recent work, which suggests that gendered organizational dynamics and initiatives play out vividly at the sub-unit level (college/department/program), depending on the centrality and status of a particular unit within the academic institution. Moreover, Gelbgiser & Alon's (2016) research on racialized organizational dynamics suggests that institutional factors post-matriculation affect the size of racial gaps in degrees earned in non-math vs. math-oriented vs. math-intensive fields [13], [25].

Building on these insights, our cross-sectional analyses seek to identify key institutional factors from the four "clusters" above associated with the well-known, persistently skewed sex composition of CS&E fields.

How Do Institutional-Type Characteristics Matter?

The types of institutions students attend impact the fields in which they can earn degrees [42], [43]. Differentiating between public and private universities matters for multiple reasons: The ratio of students attending public vs. private post-secondary institutions has remained quite stable over the past decade or more, with roughly three out of four students attending the former, one in five attending private (not-for-profit) institutions, and the remainder attending for-profit institutions [44]. Private universities tend to have higher graduation rates than private colleges, and both have higher graduation rates than public institutions [45]. Private institutions also tend to have a stronger record regarding Title IX compliance, especially in states with higher representation of women in the legislature [46]. However, with some notable exceptions, the highest-profile CS&E programs operate at public institutions and/or at research intensive (R1) institutions – a dynamic to which we return below. Moreover, R1 institutions, which tend to be more selective and frequently offer terminal/doctoral degrees, represent just about 3 percent of all postsecondary institutions in the United States in 2017 [47].

In addition, many institutions are mission driven: Land-grant and religiously affiliated institutions, and those receiving funding from mission-driven federal agencies (e.g., Department of Defense MURI projects), prioritize initiatives that impact student body demographics and programs offered – which may, in turn, affect gender-specific majoring and graduation dynamics. The landscape of postsecondary institutions is also internally stratified: A disproportionately large number of women and African American students attend 2-year and for-profit undergraduate institutions as well as tuition-driven institutions, all of which have lower graduation rates than 4-year public or private institutions [22], [48].

How Do Institutional Demographics Matter?

Student demographic composition varies greatly across institutions. This involves racial and sex composition, plus other "non-traditional" groups (e.g., veterans, "first-gen,"/low-SES, students with disabilities) – all of which impacts student outcomes. For instance, Mullen and Baker (2018) found that lack of ethno-racial diversity is associated with greater levels of gender segregation at postsecondary institutions around the US [49]. Moreover, Historically Black Colleges and Universities (HBCUs) and Hispanic Serving Institutions (HSIs), which serve a disproportionate number of non-white students [50] and have an overall higher variance in attrition rates than Historically White Institutions (HWIs) [51]. Simultaneously, as mission-driven institutions, HBCUs/HSIs are widely known for being both selective and fostering student success by providing institutional support that may mitigate factors limiting students' academic success in predominantly white institutions. Research also suggests that Black students attending HWIs are equally or more likely than their white peers to declare a STEM major when starting their degree, but ultimately earn STEM degrees at a lower rate. Because HBCUs have higher STEM retention rates, they play a crucial role in broadening STEM participation [52], [53]. Note that HBCU and HSI institutions have a unique history and mission that should not be conflated with serving a de facto diverse student body [25].

In addition to racial composition, sex composition differs greatly across institution type. For example, in contrast to other coeducational institutions [48], [54], land-grant institutions tend to enroll predominantly male students [55]. Male students also tend to be over-represented at veteran-friendly (aka "Yellow Ribbon") institutions, even though research shows that military service is actually positively associated with earning STEM degrees, especially for women veterans [56]. Gender dynamics also affect faculty representation. Men still constitute the majority of faculty members (especially at land-grant institutions), and the representation of women faculty in STEM remains modest and differs across fields: In 2015, women comprised 37.5 percent of science and engineering faculty overall (including part-time and non-tenure track), but only 16.9 percent of tenure/tenure-track faculty in colleges of engineering, and even less in computer science [7].

How Does Institutional Selectivity Matter?

Selective post-secondary institutions have lower admission rates that favour high-school graduates with higher grades and standardized test scores. However, despite having higher GPAs on average, women are more likely than men to attend less selective colleges [22]. Although past quantitative research has shown that students at selective institutions generally are more likely to graduate in STEM majors [57], this finding was not replicated in a multilevel analysis of 23 highly selective, mostly private institutions [12]. This suggests a complex dynamic involving institutional selectivity tied to institutional sector might affect STEM-related completion patterns.

Even once enrolled, women face multiple barriers to choosing and persisting in STEM [37]. Institutional priorities related to investments into research expenditures vs. students' instructional experiences create gendered persistence patterns in STEM majors [58]. Moreover, retention and graduation rates overall are considerably lower at less selective, mostly female-dominated institutions [44].

Institutions also vary widely in how they select students based on family socioeconomic status (SES), and in the extent to which they provide need-based support, such as federally funded Pell Grants [24]. Evidence indicates that such grants increase recipients' chances of earning a degree as well as subsequent earnings [59]. However, many of the most selective colleges admit a low proportion of Pell-eligible students. The institutions that do serve a relatively high proportion of Pell-grant recipients vary widely regarding Pell student graduation rates, in the gap between Pell and non-Pell student graduation rates, and even with respect to non-academic outcomes [60], [61].

How Does Ecological Context Matter?

We use the term "ecological" to denote the context in which an institution exists. For example, institutional size may affect educational outcomes in various ways. Smaller institutions cultivate more equal representation of women in STEM fields [14]. Large institutions tend to have larger classes, especially at introductory levels, which affects student persistence [62]. Many introductory STEM courses are taught in large lecture format, and students often consider these courses as "uninspiring," [63] or intimidating (see gendered "imposter syndrome" as discussed by Lindemann et al., 2016 [64]). Student-faculty ratios also matter in predicable ways for outcomes related to achievement [64], recruitment, and retention [65], [66].

Geographic context also matters. Just as students' own geographic background affects choice of post-secondary institution, the location of institutions, in turn, can also shape the college experience in multiple ways. For example, though few studies exist examining how the physical location of institutions affects postsecondary outcomes and trajectories (e.g., rural/urban, and distance from home), urbanicity is known to impact infrastructure and student outcomes [67].

Moreover, political or at least policy priorities matter. Being located in/near a state capitol [68], or in a state with stronger political representation for women [46] both impact student outcomes positively. In addition, institutional reliance on non-tuition based funding streams, and access to federal funds aimed at broadening postsecondary opportunities in rural states (e.g., the federally funded Established Program to Stimulate Competitive Research/EPSCoR), impacts student experiences [55], [60], [61]. Recent research even suggests that changes in public opinion regarding government support for higher education may be associated with shifting funding levels for public colleges and universities [69].

Materials and Methods

Data Source

We use 2015 data from the Integrated Postsecondary Education Data System (IPEDS), an annual survey of all postsecondary U.S. educational institutions (N=7,647 in 2015), conducted through the Institute of Education Sciences (IES) and the National Center for Education Statistics (NCES) and sponsored by the United States Department of Education.

The IPEDS is a unique, comprehensive data source for information about postsecondary education at the institutional level. Just as important for our analysis, it organizes postsecondary programs offered using the Classification of Instructional Programs/CIP 2000 system that provides a standardized taxonomy for classifying diverse instructional programs [70]. We aggregate the sex composition of degrees earned for two subsamples: institutions that include an engineering program (which almost invariably means they also offer computer science), and those institutions that offer only a computer science program (but not engineering). For brevity, we will refer to these two subsamples as engineering (ENG) and computer science only (CS) separately, and as CS&E together.

Our reliance on CIP codes to identify relevant CS&E fields (rather than the fuzzier term "majors") follows standard practice (e.g., Hardy and Katsinas 2010 [14]). To calculate sex composition of degrees, we identified the following widely recognized fields: All our analyses include institutions offering at least one of nine (9) Computer Science CIP fields (Computer and Information Sciences, Information Technology, Computer Programming, Information Science, Computer Systems Analyst, Computer Science, Computer Systems

Networking, Network and System, and Computer and Information). Similarly, all our analyses include institutions offering at least one of ten (10) Engineering CIP fields (Engineering, general; Bioengineering and Biomedical Engineering; Chemical Engineering; Civil Engineering; Computer Engineering, general; Electrical and Electronic Engineering; Environmental Engineering; Mechanical Engineering; Industrial Engineering; and Electrical, Electronic Engineering).

Sample

CS&E programs are not ubiquitous, nor are they distributed randomly. IPEDS (2015) reports data on a total of 7,647 post-secondary institutions. For our analytical sample, we excluded institutions that did not offer at least a bachelor's degree, were purely administrative or inactive, or were for-profit or exclusively online-distance institutions. We omitted schools enrolling fewer than 5,000 total (undergraduate and graduate) students, because they produce few graduates in our focal STEM fields. We also excluded institutions that did not report any graduating students in 2015, institutions lacking a tenure-track system, and two outliers that reported zero faculty and all women graduates, respectively. We excluded schools missing information needed for our key independent variables. We also excluded institutions that failed to offer degrees in any of the 19 central ENG or CS CIP codes discussed above.

Despite these stringent exclusion criteria, our final analytic sample of 525 institutions includes virtually all (99%) institutions that offer a CS and/or ENG degree in at least one of these 19 common CIP fields, and by implication the vast majority of CS&E graduates. Our final analytic subsamples comprise 517 institutions offering at least one of nine CS programs and 322 institutions offering at least one of ten ENG programs, with an overlap of 314 institutions offering both CS and ENG.[1] The sex composition for CS (.16) and ENG (.18) graduates in our sample closely matches national statistics, though it is slightly lower, perhaps due to our exclusion criteria (National Science Board, 2018). Just as importantly, despite these exclusion criteria, our analytic sample of institutions retains significant variation regarding institutional types, demographics, selectivity, and ecological context. This allows us to examine how specific institutional characteristics relate to the sex composition among CS&E graduates across the country.

Variables

We use two <u>dependent variables</u> for separate analyses, one for computer science (CS) and one for engineering (ENG). To predict the proportion of degrees in each field completed by women, we first calculated the total number of women who completed a B.A. in one of the focal CS (or ENG) fields per institution and divided it by the total number of CS (or ENG) degrees earned at the institution.

Multivariate models include 23 <u>independent variables</u>, grouped into four specific "clusters" discussed above. We include seven indicators to gauge institutional-type characteristics: institutional sector (public or private 4-year institution; 1=private), land-grant institution (1=yes), religiously-affiliated institution (1=yes), institution is Carnegie classified as having highest research activity (R1) (1=yes), total number of CS and ENG CIP fields actually offered at the institution (range 1-12), student-to-faculty ratio, and whether the institution received funding from the U.S. Department of Defense Multidisciplinary University Research Initiative (MURI) aimed at engineering research in 2015 (1=yes).

[1] Of the first subgroup of 517 institutions, 203 offered a CS program but no engineering program, whereas of the subgroup of 322, only 8 institutions offered a program in engineering but not in CS. Thus, the overall analytic sample is 517+8=525 institutions.

We use eight indicators to assess institutional demographics: Historically Black Colleges and Universities/HBCU (1=yes), Hispanic Serving Institution/HSI (1=yes), proportion African American students, proportion Hispanic/Latino students, proportion Asian students, proportion women students, proportion of women faculty, and veteran-friendly or "Yellow Ribbon" institution (1=yes). IPEDS provided HBCUs and Yellow Ribbon identifiers. We created an HSI measure using the Hispanic Association of Colleges and Universities list (HACU 2015). We created measures for the proportion of women, African American, Hispanic/Latino, and Asian student enrollment by dividing total student enrollment for each group by total student enrollment at the institution. We calculated the proportion of women faculty by dividing the total number of women holding instructional rank by the total number of faculty holding instructional rank.

Note that our final model also includes interaction terms that cross these "clusters." Building on Mullen and Baker (2018) we report interaction terms that gauge the impact of the proportion of non-white students and of women at the institution to gauge the complexities of group-level intersectional dynamics [49]. We also report interaction terms that gauge the impact of the proportion of non-white students at private (vs. public) 4-year institutions because of sector-specific desegregation legacies.[2]

To assess institutional selectivity, we use four IPEDS measures: institutional retention rate, proportion students receiving Pell grants, proportion of applicants whose ACT scores are at least at the 75th percentile, and proportion tuition-reliance. IPEDS included information on the first three measures. We created a tuition-reliance measure by dividing the total reported revenue collected through tuition and fees by the total reported revenue collected through all sources (e.g., investments, endowments).

To gauge ecological context, we assess institutional size using three categories (student enrollment, where 0=5,000-9,999, 1=10,000-19,999, and 2=20,000+). We use two dichotomous indicators to gauge location: urban area (1= city; 0= otherwise, based on Census classification), and political centrality (1=state capitol). A dummy variable indicates being part of the EPSCoR program to capture the general funding environment (1=yes, n=137 institutions across 31 states).

Analytic Strategy

We use ordinary least squares regression models to assess sex composition of CS&E degrees (reporting coefficients plus standardized betas to facilitate comparisons of effect sizes). Continuous variables were mean-centered so that the constant can be interpreted as the value of the dependent variable for all omitted categories and as the average of continuous variables.

We use multiple imputation using chained equations (see White, Royston, and Wood, 2011) across 20 multiply imputed datasets using the Stata 13's "ice" command and "mi suite." Instead of imputing values on the dependent variables, we included them in the imputation models. To adjust for intragroup correlations, we estimated models using clustered standard errors (e.g., Smyth & McArdle, 2004). Table 1 shows percent missing values across all independent variables in the final analytic sample. In multivariate analyses (Tables 2 and 3), we present partial models (Models 1A-4A for CS, Models 1B-4B for ENG), the full model (Model 5A for CS, Model 5B for ENG), and a final model with two sets of interaction terms motivated by results from prior models (Model 6A for CS, 6B for ENG).

[2] In ancillary analyses, we tested additional interaction terms but found few systematic patterns. Results available on request.

Results

Descriptive Statistics

Table 1 shows descriptive statistics for institutions that had one or more of the 19 programs in CS (n=517 institutions) or ENG (n=322 institutions). It shows that women comprised approximately 16 percent of degree earners in CS programs and 18 percent in ENG programs. Women made up approximately 55 percent of students enrolled at institutions with one or more CS programs (53 percent for those with ENG programs), and about 44 percent of faculty holding instructional rank institutions with one or more CS programs (41 percent for those with ENG programs). Most sample institutions were public, 4-year institutions (74 percent for CS vs. 77 percent for ENG degree institutions). In addition, 21 percent of institutions offering CS degrees were classified as research-intensive “R1” institutions, compared to 32 percent of those offering ENG degrees.

In addition, institutions with ENG programs are overrepresented among grant institutions (18 percent) and those receiving MURI funding (14 percent) (compared to 11 and 9 percent, respectively, for those with CS programs).

Table 1. Descriptive Statistics for All Institutions Offering Computer Science and/or Engineering Programs (N=525)

	Computer Science (N=517)					Engineering (N=322)					
Dependent variables:	Mean	SD	Min	Max	% miss	Mean	SD	Min	Max	% miss	Dif
Computer Science – % degrees earned by women	.16	.10	0	.75	0						
Engineering – % degrees earned by women						.18	.10	0	.64	0	
Independent variables:											
Institutional-type characteristics											
Public 4-year	.74		0	1	0	.77		0	1	0	
Private 4-year	.26		0	1	0	.23		0	1	0	
Land grant institution	.11		0	1	0	.18		0	1	0	*
Religious university	.11		0	1	0	.07		0	1	0	*
Highest research institution (R1)	.21		0	1	0	.32		0	1	0	*
Number of programs (CS and ENG[1])	4.54	2.97	1	12	0	6.30	2.39	1	12	0	*
Student-to-faculty ratio	17.11	4.47	3	33	0	17.25	4.80	3	33	0	*
MURI funding	.09		0	1	0	.14		0	1	0	*
Institutional demographics											
Historically Black college	.03		0	1	0	.03		0	1	0	
Hispanic serving institution	.11		0	1	0	.13		0	1	0	
Proportion African American enrollment [3]	.11	.15	.00	.91	.07	.10	.14	.00	.91	.08	
Proportion Hispanic/Latino enrollment	.13	.15	.01	1	.07	.12	.14	.01	.92	.08	
Proportion Asian enrollment	.06	.06	.00	.37	.07	.07	.07	.00	.37	.08	
Proportion women enrollment	.55	.08	.20	.78	.07	.53	.07	.20	.69	.08	*
Proportion women with faculty instructional rank	.44	.09	.11	.78	.01	.41	.09	.11	.73	.02	*
Yellow Ribbon institution	.71		0	1	0	.72	.45	0	1	0	
Institutional selectivity											
Proportion institutional retention	.80	.10	.46	1	.01	.82	.10	.46	.99	.01	
Proportion tuition-reliance	.37	.19	.02	.91	.03	.34	.17	.02	.87	.03	
Proportion undergraduate Pell grants	.34	.14	.07	.86	0	.32	.14	.07	.82	0	
Proportion 75% ACT scores	26.60	3.54	19	35	.17	27.33	3.63	19	35	.11	*
Ecological characteristics											
Institutional size (range 0-2)	.90	.82	0	2	0	1.18	.81	0	2	0	*
Urban	.61		0	1	0	.65		0	1	0	
State capitol	.08		0	1	0	.09		0	1	0	
EPSCoR state	.26		0	1	0	.27		0	1	0	

N=525

[1]: CS = Computer Science, ENG = Engineering

[2]: Chi-square tests of differences

[3]: Total student enrollment variables (i.e. total women, African American, Hispanic/Latino, Asian enrollment) refers to total undergraduate student enrollments.

Multivariate Results

Computer Science

Table 2 shows results for the percent of degrees from CS programs earned by women. Partial model 1A for institutional-type characteristics suggests that most factors related to institutional type do not appear to have a measurable impact on our outcome. However, a one-unit increase in student-to-faculty ratio is associated with a .004 ($p<.001$) decrease in the proportion of women completing a CS degree. To put this into context, 15.7 percent of women in Model 1 completed a degree in CS. If we increased the student-faculty ratio (increased the number of students per faculty) to one standard deviation above the mean (from 17.5:1 to 22:1 student to faculty ratio) the proportion of women completing a CS degree would drop to 14 percent, almost two percentage points. This effect remains quite stable across models.

Partial model 2A shows that institutional demographics are associated with sex composition of CS degrees. HBCUs graduate .147 ($p<.001$), or 14.7 percentage points, more women from CS programs than non-HBCU institutions. Yellow Ribbon institutions graduate .025 ($p<.01$), or 2.5 percentage points, more women from CS programs compared to non-Yellow Ribbon institutions. In addition, as the proportion of Asian students increases, so does the proportion of women completing CS degrees ($B=.240$, $p<.001$), but like the "Yellow Ribbon" effect, this is not significant in the full models. Instead, the proportion of Latinx students seems to be positively related to our outcome in the full models ($B=.121$, $p<.05$).

Partial model 3A suggests that institutional selectivity is not associated with sex composition of CS degrees. However, in the full model 5A, the strong effect of Pell grant recipients become evident: The higher the proportion of undergraduate students receiving Pell grants, the lower the proportion CS degrees completed by women (-.214, $p<.001$). This is one of the strongest effects of any variable included in our models (see standardized betas) and indicates that the sex composition of students earning a CS degree is even more heavily skewed towards men at institutions with higher representation of students from low-SES families. We will return to this intriguing juxtaposition in our discussion of intersectionality effects below.

Partial model 4A at first suggests that ecological factors also play a role: At larger institutions, women earn a smaller proportion of CS degrees (-.012, $p<.05$). Institutions located in urban areas see a higher proportion of CS degrees completed by women (.025, $p<.01$). However, both effects drop out in the full model (5A), when we take other population-based factors such as student-faculty ratios into account.

Model 5A, the full model, constitutes a marked improvement over any of the partial models. It explains 22 percent of the variance in the proportion of degrees in CS earned by women. Model 5A shows that key results from the partial models remain stable when controlling for other variables: higher student-to-faculty ratios continue to be associated with a lower proportion CS degrees earned by women. Additionally, HBCUs continue to produce a larger proportion of CS degrees for women (.128, $p<.01$).

The full model also reveals key suppression effects related to three of the variables from our partial models: As the proportions of African American (.204, $p<.001$) and Hispanic/Latino (.121, $p<.05$) students increase, so does the proportion of women completing CS degrees. As mentioned above, the proportion of degrees from CS programs earned by women decreases as the share of undergraduate students receiving Pell grants increases (-.214, $p<.001$). This indicates that, at institutions with more students from low-SES families, a larger than usual proportion of CS degrees are earned by men.

In light of the intriguing combination of effects possibly suggesting a countervailing intersectional impact of racial vs. SES diversity we introduce six interaction terms in Model 6A: three interaction terms for institutional sector (i.e., public or private 4-year) by proportion racial/ethnic minority enrollment, and three interaction terms for proportion women enrollment by racial/ethnic minority enrollments. Notably, while we found only one statistically significant interaction for CS, our model fit continues to improve.

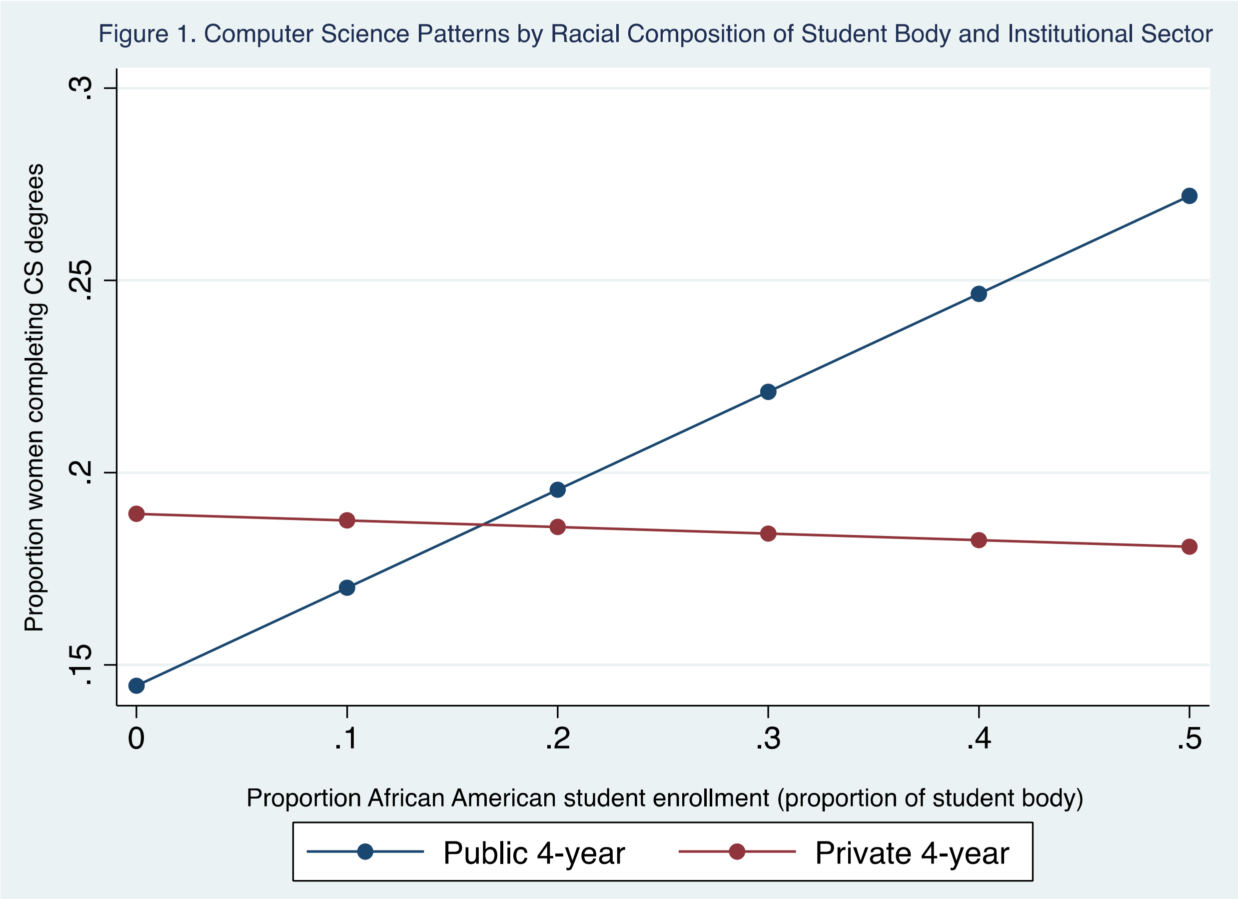
We refer readers to Figure 1, for ease of interpretation: It shows a strong relationship between the proportion of African American students and the proportion of CS degrees women earn, by institutional sector. After controlling for other variables (and most importantly, for the effect of HBCUs), the plot shows that at 5 percent African American student enrollment, women's proportion of CS degrees is lower at public 4-year institutions (about 16 percent) compared to private 4-year institutions (about 18 percent). However, as the proportion of African American student enrollment increases, the proportion of CS graduates who are women also increases at public 4-year institutions. Because their proportion at private institutions remains relatively flat, women's share of CS degrees earned at public schools quickly outpaces private institutions. To put this into context, in our sample, the average proportion of African American enrollment was .11 with a SD of .15 (see Table 1)**.** At one standard deviation above the mean (.26 (=26 percent) African American), the proportion of women CS graduates at public 4-year institutions (22% and rising) clearly outstrips trends at private 4-year institutions (18% and falling).

Table 2. Percent of Baccalaureate Degrees Earned by Women: All Institutions Offering Computer Science Programs (N=517)

	Model 1A			Model 2A			Model 3A			Model 4A			Model 5A			Model 6A		
	B	SE	STD B[1]	B	SE	STD B	B	SE	STD B	B	SE	STD B	B	SE	STD B	B	SE	STD B
Institutional-type characteristics																		
Private 4-year	.026	.015	.113										.009	.017	.038	.000	.019	.001
Land grant institution	.004	.015	.014										-.014	.012	-.044	-.013	.012	-.041
Religious university	-.006	.022	-.018										-.004	.022	-.012	-.009	.022	-.027
Highest research institution (R1)	.019	.012	.079										.019	.013	.077	.018	.014	.075
Number of programs (CS and ENG)	-.002	.002	-.064										-.002	.002	-.064	-.002	.002	-.057
Student-to-faculty ratio	-.004 ***	.001	-.170										-.003 *	.001	-.134	-.003 *	.001	-.126
MURI funding	-.001	.012	-.002										-.004	.013	-.011	-.001	.014	-.002
Institutional demographics																		
Historically Black college				.147 ***	.042	.256							.128 **	.047	.222	.115 *	.045	.200
Hispanic serving institution				-.001	.018	-.004							.020	.018	.065	.024	.018	.077
Proportion African American enrollment				.060	.049	.089							.204 ***	.060	.303	.252 ***	.056	.375
Proportion Hispanic/Latino enrollment				.031	.036	.047							.121 *	.048	.185	.114 *	.053	.174
Proportion Asian enrollment				.240 ***	.068	.156							.131	.080	.085	.134	.084	.087
Proportion women enrollment				.079	.083	.060							.032	.097	.024	.052	.095	.040
Proportion women with faculty instructional rank				-.003	.074	-.002							.045	.077	.041	.044	.074	.040
Yellow Ribbon institution				.025 **	.009	.115							-.001	.010	-.003	.003	.010	.012
Selectivity factors																		
Proportion institutional retention							.139	.073	.138				-.050	.086	-.049	-.085	.089	-.084
Proportion tuition-reliance							.028	.025	.053				.020	.032	.039	.033	.036	.064
Proportion undergraduate Pell grants							.043	.049	.060				-.214 ***	.066	-.298	-.200 **	.069	-.279
75% ACT scores							.000	.002	.004				.002	.003	.064	.003	.003	.108
Ecological factors																		
Institutional size (range 0-2)										-.012 *	.005	-.096	.001	.007	.011	.003	.007	.023
Urban										.025 **	.009	.124	.009	.009	.045	.006	.009	.028
State capitol										.024	.018	.063	-.001	.015	-.004	-.005	.015	-.013
EPSCoR state										-.017	.010	-.075	.005	.011	.020	.003	.011	.012
Interactions																		
Private 4-year*African American enrollment																-.264 ***	.076	-.135
Private 4-year*Hispanic/Latino enrollment																-.096	.118	-.084
Private 4-year*Asian enrollment																-.006	.191	-.002
Proportion women*African American enrollment																-.133	.728	-.013
Proportion women*Hispanic/Latino enrollment																.521	.457	.103
Proportion women*Asian enrollment																.445	.779	.029
Intercept	.157 ***	.009		.135 ***	.007		.158 ***	.004		.156 ***	.008		.150 ***	.012		.148 ***	.013	
R2	.067			.128			.015			.030			.220			.242		

[1]: Standardized beta; N=517; Note: *p<.05, **p<.01, ***p<.001

Figure 1. Computer Science Patterns by Racial Composition of Student Body and Institutional Sector



Engineering

Table 3 shows results for the percent of degrees from engineering programs earned by women. Model fit statistics male it immediately apparent that institutional dynamics exert a far stronger influence on our outcome for engineering graduates.

Specifically, in contrast to CS (Table 2), partial model 1B shows relatively strong impact based on institutional-type characteristics: Specifically, private 4-year colleges (.087, p<.001) are associated with higher representation of women among ENG graduates. This effect is robust and persists in the full model. Moreover, R1 institutions (.041, p<.01), as well as those receiving significant federal funding related to the Department of Defense (MURI; B=.025, p<.05), appear associated with higher sex composition of ENG degrees. And similar to CS, higher student-to-faculty ratio is associated with a -.003 (p<.01) decrease in women's representation among engineering graduates. Note that, while none of these sectoral effects persist in the full model (5B), this is by far the best partial model, as it explains an impressive 36% of the variance in the proportion of degrees in ENG earned by women.

Partial model 2B on institutional demographics shows that, similar to CS, HBCUs (.169, p<.01) and Yellow Ribbon institutions (.062, p<.001), as well as the proportion of Asian students (.412, p<.001) are positively associated with a higher proportion of women completing an ENG degree. Once again, we observe a shift in how institutional racial demographics matter in the full model (5B), in that the proportion of students who are Hispanic/Latinx emerges as one of the strongest predictors overall – in this case overpowering other indicators of demographic diversity. Together, this combination of findings once again signals that racial diversity in the overall student body seems to have a positive effect on the representation of women among ENG degree earners.

Partial model 3B on institutional selectivity shows that, unlike in CS models (Table 2), the proportion of high-performing students (ACT at or above 75th percentile) is positively associated with the proportion of ENG degrees women complete (.017, p<.001). This effect persists in the full model 5B, where it is joined by significant coefficients for tuition dependency and reliance on Pell-grant funded students. In a similarity with CS, the representation of women among ENG degrees earned suffers at institutions where a larger share of students relies on need-based Pell grants (which might be viewed as a proxy for first-generation/working-class students). Put differently, the combination of these findings suggests that the sex composition of ENG (and CS) graduates is strongly affected by factors related to the students' financial resources and SES background.

Partial model 4B suggests once again that ecological factors play a role: I institutions located in urban areas see a higher proportion of ENG degrees completed by women (.026, p<.05), as does being located in the political center of the state, possibly because it facilitates access to policy makers and agencies. However, just like in Table 2, these contextual factors drop out in the full model.

Notably, Model 5B, our full model, explains 51 percent of the variance in the proportion of ENG degrees earned by women -- more than twice the variance explained with the same model for CS. For example, model 5B shows that the positive effect of private 4-year institutions on our outcome remains robust (.057, p<.01). Similar to Table 2, Model 5A, the proportion of Hispanic/Latinx students now emerges as significant and positively related to the proportion of women earning ENG degrees (.168, p<.01). Rather than concluding that racial diversity effects appear fickle, it is worth pointing out that as our models expand, we repeatedly demonstrate a shift in which specific aspect of racial diversity is highlighted for its impacts on gender representation in both fields. In this case, the proportion of students who are Hispanic/Latinx (rather than Asian or attending an HBCU) emerges as key predictor of how well women are represented among ENG degree earners (see standardized betas). Otherwise, neither factors related to institutional type nor to institutional demographics appear to affect the sex composition of ENG degrees in the full model.

To summarize, Model 5B reveals a clear and unique suppression pattern for ENG programs that points towards the importance of institutional selectivity, especially at the intersection of gender and SES-based dynamics. The measure of overall tuition-reliance emerges as significant, indicating that the sex composition of ENG degrees earned at institutions relying more heavily on tuition revenue is more skewed towards men (-.090, $p<.05$). Similar to CS, institutions with a higher proportion of undergraduates receiving Pell Grants also had a lower representation of women among students who complete degrees in ENG programs (-.138, $p<.05$). Given that ENG programs (like CS) frequently charge higher tuition than other programs/units even at the same institution, this may suggest that heavily tuition-dependent institutions with ENG programs inadvertently create a barrier to entering engineering for students who are female and/or those who come from lower-income families.

That institutional selectivity plays a key role in shaping the representation of women among ENG degree earners is further driven home by our measure for academic selectivity (ACT 75^{th} percentile or above) in Model 5B. Specifically, at institutions with a higher proportion of high-performing students, women also comprise a larger share of those earning ENG degrees (.014, $p<.001$). It is well known that higher scores on standardized tests (such as the ACT) are positively associated with family SES. This combination of factors suggests that family SES, including but not limited to financial resources, affect from the sex composition of ENG (and to some degree CS) degrees at the institutional level.

Model 6B introduces the same six interaction terms also displayed in Table 2 (Model 6A). A general comparison of Tables 2 and 3 shows that far fewer institutional factors influence the sex composition of degrees earned in ENG than the sex composition of CS degrees: Table 2 showed that, for CS, a combination of institutional demographics and diversity play a far more prominent role. Table 3 shows that, for ENG, just three factors remain robust predictors, with institutional selectivity (ACT scores) having the biggest impact on the sex composition of degrees earned. Especially for ENG, this indicates covariation between institutional dependence on tuition, the proportion of students receiving Pell grants, and the interaction term discussed below.

In contrast to CS, adding interactions does not improve the ENG model much further, though the model fit for ENG (52%) clearly surpasses that for the CS model (24% of variance). Only the interaction of institution type (public/private) with the proportion of African American students is statistically significant – and its effects on the sex composition of ENG degrees are opposite from its effect on CS degrees: Whereas the representation of women among ENG degree earners is boosted at private 4-year institutions with higher African American student enrollment, women's representation among CS degree earners suffered in similar institutions.

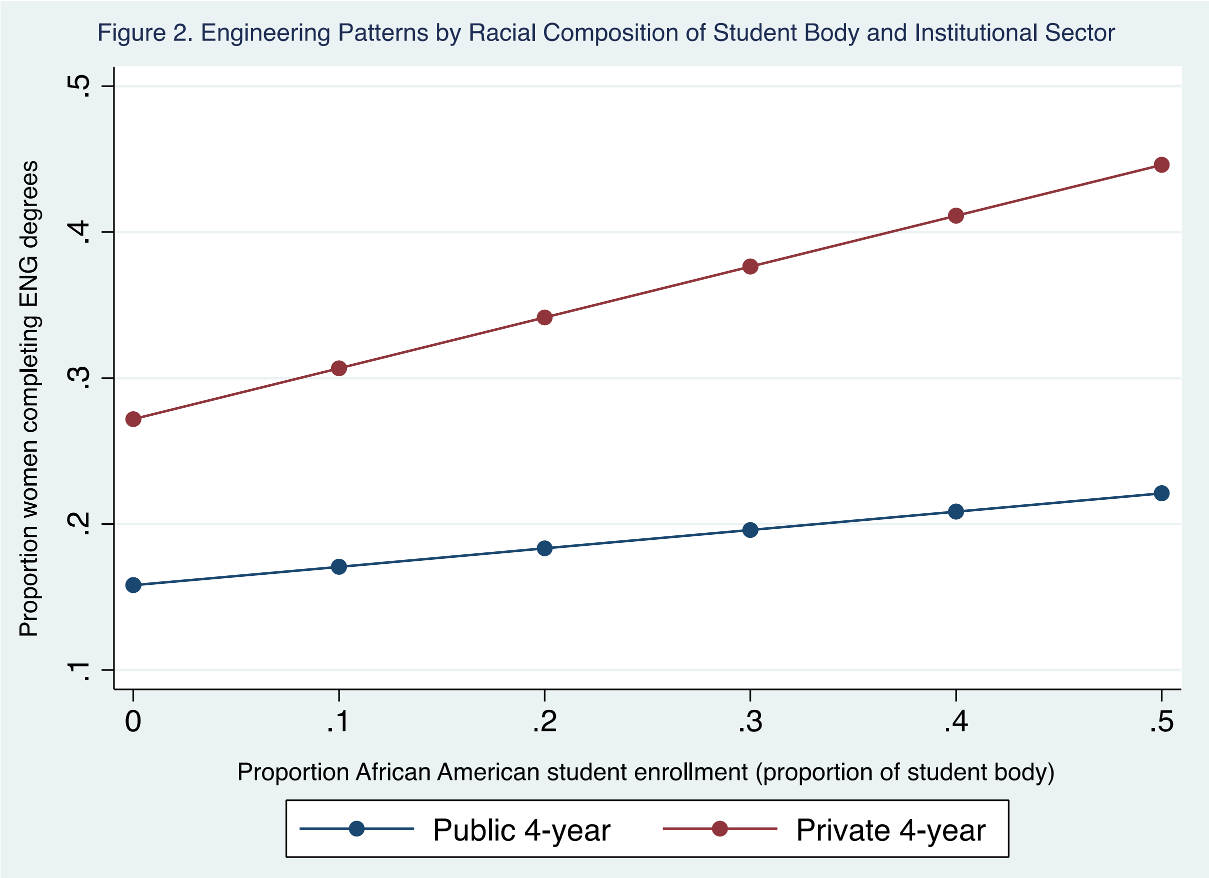
Once again, we turn to a visual representation to highlight the difference in findings between CS and ENG trends: Figures 1 and 2 show the interaction between the proportion of African American enrollment and the proportion of degrees women completed, by institutional sector. In Figure 1, we showed that public institutions with a higher proportion of students who are African American also tend to have a higher proportion of CS degrees earned by women. In contrast, Figure 2 shows that private institutions consistently outpace public ones with respect to ENG degrees earned by women, regardless of the level of racial diversity (% African American) and controlling for other factors (including HBCUs): At public 4-year institutions, where 5 percent of enrolled students are African American, women complete approximately 16 percent of ENG degrees vs. about 30 percent of ENG degrees at private 4-year institutions. In addition, women's representation in ENG increases more considerably at private 4-year institutions compared to public 4-year institutions as African American student enrollment increases. To put this into context, at one standard deviation above the mean (26 percent African American student enrollment), women complete approximately 19 percent of engineering degrees at public 4-year institutions, compared to approximately 36 percent at private 4-year institutions. At two standard deviations above the mean (~ 41 percent African American), women complete approximately 21 percent of ENG degrees at public 4-year institutions compared to 41 percent of ENG degrees at private 4-year.

Table 3. Percent Baccalaureate Degrees Earned by Women: All Institutions Offering Engineering Programs (N=322)

	Model 1B			Model 2B			Model 3B			Model 4B			Model 5B			Model 6B		
	B	SE	STD B[1]	B	SE	STD B	B	SE	STD B	B	SE	STD B	B	SE	STD B	B	SE	STD B
Institutional-type characteristics																		
Private 4-year	.087 ***	.018	.371										.057 **	.019	.241	.050 *	.022	.211
Land grant institution	.015	.010	.057										-.001	.009	-.005	.000	.009	-.001
Religious university	-.035	.024	-.090										-.032	.021	-.083	-.016	.025	-.041
Highest research institution (R1)	.041 ***	.010	.194										.012	.012	.056	.016	.012	.076
Number of programs (CS and ENG)	.004	.002	.095										.003	.003	.080	.003	.003	.077
Student-to-faculty ratio	-.003 **	.001	-.166										.000	.002	-.018	.000	.002	-.007
MURI funding	.025 *	.011	.086										-.003	.012	-.011	-.002	.012	-.008
Institutional demographics																		
Historically Black college				.169 **	.060	.308							.091	.065	.167	.100	.064	.182
Hispanic serving institution				-.020	.022	-.067							.014	.023	.049	.020	.024	.068
Proportion African American enrollment				-.079	.080	-.115							.136	.097	.198	.099	.102	.144
Proportion Hispanic/Latino enrollment				.059	.047	.083							.168 **	.057	.236	.151 *	.061	.212
Proportion Asian enrollment				.412 ***	.074	.293							.087	.062	.062	.055	.068	.039
Proportion women enrollment				-.118	.087	-.087							.005	.081	.004	-.006	.081	-.004
Proportion women with faculty instructional rank				-.061	.072	-.052							.090	.058	.078	.044	.068	.038
Yellow Ribbon institution				.062 ***	.011	.281							.020	.013	.090	.015	.013	.070
Selectivity factors																		
Proportion institutional retention							.041	.089	.041				-.106	.091	-.108	-.102	.087	-.103
Proportion tuition-reliance							-.032	.029	-.054				-.090 *	.039	-.149	-.073	.040	-.122
Proportion undergraduate Pell grants							.094	.052	.129				-.138 *	.067	-.191	-.129	.068	-.178
75% ACT scores							.017 ***	.003	.599				.014 ***	.003	.511	.014 ***	.003	.491
Ecological factors																		
Institutional size (range 0-2)										-.007	.007	-.096	-.014	.008	-.114	-.015	.008	-.122
Urban										.026 *	.012	.124	.009	.010	.041	.008	.010	.038
State capitol										.032 *	.016	.063	.004	.013	.011	.009	.013	.025
EPSCoR state										-.014	.012	-.075	.004	.012	.020	.005	.013	.024
Interactions																		
Private 4-year*African American enrollment																.185 **	.070	.099
Private 4-year*Hispanic/Latino enrollment																-.156	.136	-.058
Private 4-year*Asian enrollment																.261	.187	.085
Proportion women*African American enrollment																-.449	.759	-.032
Proportion women*Hispanic/Latino enrollment																-.609	.425	-.061
Proportion women*Asian enrollment																.133	.585	.010
Intercept	.117 ***	.017		.122 ***	.010		.168 ***	.005		.171 ***	.013		.124 ***	.018		.127 ***	.019	
R2	.359			.215			.307			.030			.505			.519		

[1]: Standardized beta; N=322; Note: *p<.05, **p<.01, ***p<.001

Figure 2. Engineering Patterns by Racial Composition of Student Body and Institutional Sector



Discussion

What Do Our Findings Mean for Researchers and Institutions?

This study explores how institutional dynamics -- type, demographics, selectivity, ecological factors -- are related to the sex composition of CS&E degrees earned at U.S. postsecondary institutions. Our sample of institutions is based on IPEDS 2015 data and represents 99% of all institutions offering CS&E degrees. Our analyses are grounded in a theoretical perspective that regards postsecondary educational institutions as an example of gendered organizations. We recap and interpret analytical results below in order of importance, to highlight our contribution to understanding persistent gender disparities in CS&E. We conclude by identifying field- and/or institutional-level (rather than individual-level) factors that are key to meaningful interventions designed to advance women's representation in these two male-dominated fields.

1. Racial diversity at the institutional level fosters gender diversity at the programmatic level, specifically in CS&E programs.

This finding points to important commonalities worth highlighting, despite some key differences between CS and ENG discussed further below. Most importantly, institutional demographics related to racial composition are key to explaining the variation in the proportion of CS&E degrees completed by women. Specifically, HBCUs as well as other institutions with a critical mass of Latinx and African American students appear to foster greater representation of women among CS degree earners. Similarly, for institutions offering ENG programs, institutional demographics related to socioeconomic and ethnic diversity (HBCU, Yellow Ribbon, proportion Asian in model 2; proportion Latinx) are positively associated with the proportion of women completing degrees from ENG programs. Note also that neither the sheer representation of women as students (percent enrollment) nor as faculty members is related to the proportion of CS&E degrees completed by women.

Our findings suggest that that, while postsecondary institutions are no doubt gendered organizations in terms of representation, practices and culture/ethos, these gendered organizations also can impact multidimensional inequalities ("inequality regimes"), with intended and unintended consequences [8], [15], [16], [17], [18], [19]. This helps explain the complexity of our findings, which suggest that institutional commitment to serving historically marginalized groups (HBCU, HSI) and fostering student diversity in one dimension (here: racial composition) has demonstrable repercussions for broadening participation in another dimension (here: gender composition).

Our findings also imply that institutional efforts to broaden participation in STEM are fundamentally linked to general recruitment practices, across CS&E fields and demographic groups. A simple "add [women] and stir" approach to overall recruitment/enrollments will not change gender dynamics in male-dominated STEM fields. The potential lesson for postsecondary institutions may be that failure to recruit generally inclusive incoming cohorts exacerbates gender inequalities in STEM degrees across these fields. Put differently, even though public discourse about intersectionality most often ties the concept to individuals and identities, our analysis shows that intersectionality effects permeate all levels of analysis. In this case, meso-level (institutional) dynamics related to racial composition affect the gender composition in specific STEM fields.

2. Women's representation in Engineering programs is largely driven by institutional characteristics.

We now turn to key differences between CS and ENG. Specifically, only in ENG do institutional-type characteristics actually explain the lion's share of variation in women's representation. Indeed, for ENG, the partial model containing solely institutional size and sector has more explanatory power in predicting the proportion of women completing degrees (36 percent) than even the full model does for CS. Specifically, while private 4-year institutions have played a key role in boosting women's representation in ENG degrees, public institutions have done the same for CS. We can only speculate why the effect of institutional type on women's representation differs across fields: Quite possibly, unmeasured covariates associated with private vs. public institutions explain this pattern, including sectoral differences in funding streams, student demographics, and selectivity factors. While IPEDS data are not suited to explore the mechanisms cited above, future research should examine these dynamics in more detail.

3. The success of future efforts to improve the representation of women in Engineering will depend heavily on leadership initiatives taken by research-intensive (R1) institutions.

Research-intensive (R1) institutions, both public and private, appear to have significant potential to help boost the proportion of women who complete ENG degrees, perhaps because within the select group of institutions offering ENG programs, they are central to the institutional mission. Our findings lead us to concur with empirical research suggesting that efforts to diversify the pool of STEM graduates are more successful if programs or departments constitute a core part of the organization and possess "a high level of material and social resources" [13, p. 609]. We point to this particular dynamic, because R1 institutions are also selective institutions that play a key role in producing engineers, making them appealing for initiatives designed to broaden participation. They also are generally well-funded, which might create opportunities to provide tuition support to students in need. Targeted interventions might focus on the role of research-intensive institutions and the ways in which they engage undergraduate students successfully in basic and applied research.

Thus, rather than calling for another nationwide or discipline-based initiative, targeted interventions to diversify ENG cohorts might focus on the few key institutions already fitting this combination of institutional characteristics: institutions that are private, research-intensive, supported by the Department of Defense (MURI), and known for small student-faculty ratios. On one hand, such institutions could continue to provide leadership on how to advance women's representation in these fields. On the other hand, they could share concrete lessons regarding best practices with other institutions not yet known for their success in this matter, including public R1 institutions, given that public universities are responsible for producing roughly three out of four engineering graduates [71].

4. The success of future efforts to improve the representation of women in Engineering will depend heavily on providing scholarships at academically selective institutions.

Third, for ENG, institutional selectivity (as well as the demographic diversity discussed above) also appears key, explaining over half of the variation in the proportion ENG graduates who are women. Specifically, institutions recruiting more students who already performed well in high school (ACT score) also tend to produce a higher proportion of women ENG graduates. In contrast, institutional reliance on tuition and on Pell grants decreases the proportion of women ENG graduates. Note that these selectivity factors all gauge socioeconomic dynamics related to exposure and selection effects prior to entering college [12]. Given that engineering programs frequently charge higher tuition than others even at the same institution, this may suggest that heavily tuition-dependent institutions with ENG programs inadvertently create a barrier to entering engineering for students who are female and/or those who come from lower-income families (especially if access to scholarships is scarce). Existing research shows that women tend to be over-represented at tuition-driven institutions at least in part because they have less access to grants and scholarships and frequently lack family financial support [64].

5. Improving the representation of women in Computer Science likely requires more idiosyncratic, program-level initiatives aimed at recruitment and retention, rather than counting on top-down leadership initiatives.

In contrast to ENG, the factors shaping the sex composition of CS degree earners remain more challenging to pinpoint. Specifically, our analyses suggest that institutional-type characteristics play a comparatively subordinate role in shaping women's representation in CS degrees. Instead, institutional demographics provide the strongest leverage to improve gender representation in CS, pointing towards institutions that have a historical mission or contemporary record of serving historically underrepresented populations. We note again that the explanatory power of our multivariate models for women's representation in CS pales in comparison to ENG. We conclude that identifying effective interventions to improve women's representation in CS might require focusing on factors beyond institutional dynamics and involve programmatic/departmental or classic individual-level factors that affect recruitment and retention. Unfortunately, exploring those dynamics is beyond the scope of IPEDS data.

To summarize, our results reveal unexpected complexities. On one hand, some of our findings do confirm initial expectations, bolstering classic arguments that postsecondary institutions (like workplaces more generally) are fundamentally gendered institutions characterized by inequalities that require top-down, holistic, transformative strategies (Acker, 1990, 2006; Risman, 2004). On the other hand, our findings also bolster arguments more recently advanced by Correll (2017) and Fox et al. (2011) that could be viewed as challenging this classic argument [13], [17]. After all, our research shows that potential solutions to diversifying STEM fields may, in fact, depend on unit or field-specific, targeted interventions. Thus, top-down, institution-wide initiatives may inadvertently raise the risk of implementing well-intentioned policies and practices that prove ineffective or produce counterproductive consequences. Our finding that the sex composition of degrees is associated with both field-specific and institutional dynamics suggests that Correll's (2017) "small wins" approach [17] in combination with Ecklund et al.'s (2012) call to implement program-specific (college/departmental) initiatives [72] might prove more effective, at least in reducing gender disparities in some key academic fields.

What Do Our Findings Mean for Policy and Practice?

Academic institutions that seek to diversify CS&E programs must employ selectivity criteria judiciously to recruit a more socio-demographically diverse pool of students to the institution at large. To broaden participation in ENG, institutions should optimize efforts to diversify recruitment socioeconomically. To broaden participation in CS, institutions should optimize efforts to diversify recruitment demographically in every dimension possible, as our findings show that race/ethnic diversity among students overall boosts women's representation in CS. This suggests important ripple effects emanating from contemporary affirmative action initiatives whose raison d'être continues to be challenged. Efforts to optimize gender representation in these fields might involve recruitment based on academic merit coupled with efforts to offset potential financial barriers to enrollment more likely encountered by e.g., female and ethnic minority students. Such efforts might include considering alternatives to relying on differential tuition and loan-driven funding sources.

Finally, our findings have important implications for U.S. policy makers at state and federal levels. Many programs aimed at broadening participation in engineering focus on "fixing" adolescents' perceptions and science identities, with the hope that long-term trickle-down effects will yield future, larger, more diverse cohorts of STEM graduates. Our findings suggest that institutional context and conditions potentially play just as big a role as individual-level factors. Policy makers have an opportunity to incentivize institutions accordingly. In the meantime, private and other types of selective schools seem to be driving current progress regarding women's representation, especially in engineering. It appears that making institutions (and units therein) increasingly tuition dependent has created a potentially unintended consequence that highlights an internal contradiction between neoliberal financial models and classically liberal broadening participation goals: By increasing their reliance on tuition and student loans as a source of income, institutions (and ENG programs specifically) inadvertently provide disincentives for women to pursue these specific STEM degrees. Once again, we see an opportunity for policy makers to reduce financial barriers to pursuing degrees in these fields.

We conclude that, if policy makers are committed to broadening participation in CS&E fields (and in higher education at large), perhaps it is time to turn their attention back to supporting public access to institutions of higher education, rather than continuing on the path towards divestment from higher education in ways that shift the burden to institutions and their students [73]. Certainly, public opinion regarding how to finance higher education has shifted drastically in the past decade, resulting in a new wave of research that shows increasing support for publicly funded higher education, spurred not only by the escalating student debt crisis and scandals involving for-profit institutions, but also by a generational shift in how Americans prioritize the individual vs. collective benefits of higher education in ways that cross-sect and undermine ideological or partisan stances [69]. In addition, the recent wave of efforts to defund and discontinue institutional efforts to recruit and retain demographically diverse student bodies will undermine efforts to increase the representation of women in CS&E.

Directions for Future Research

Of course, our study has important limitations: We excluded for-profit institutions, online institutions, and institutions without tenure systems. Thus, our findings should not be used to generalize such institutions. Moreover, our reliance on IPEDS means we are focusing on US-based institutions and cannot extrapolate to other countries. This matters because the way in which the sex composition of STEM fields is skewed varies drastically across countries (see e.g., [74], [75], [76]. Future research might explore how country-specific parameters that shape postsecondary systems in turn affect the sex composition of STEM fields. Meantime, we remain cautiously optimistic that our research has generalizable implications, e.g., for explaining persistent gender disparities in other STEM occupations. Given that women are the largest "untapped" resource to diversify STEM fields[75], our efforts to identify key institutional dynamics may potentially help address the recruitment of historically underrepresented groups into other thriving STEM occupations [77].

Despite the comprehensiveness of IPEDS data, our cross-sectional analysis does not permit us to infer causal relationships. Only longitudinal data could pinpoint potential causal dynamics shaping the sex composition of CS and ENG fields and degrees earned. Readers might also question the use of IPEDS data from 2015. Even though institutional characteristics typically change at a glacial pace, future research might also compare waves of IPEDS pre- and post-COVID pandemic, which severely impacted student trajectories across the board. Especially in light of the disruption the recent COVID-19 pandemic has caused in higher education, a longitudinal analysis might help assess whether institutional responses to the pandemic (e.g., waiving SAT/ACT requirements or application fees) have had a measurable impact on gender (and racial) representation in CS&E fields, and STEM fields at large.

We have also stressed that IPEDS focuses on capturing institutional-level dynamics. This limitation inherent to IPEDS means that we cannot disentangle how institutional vs. sub-institutional (college/unit) level dynamics might affect our outcome of interest. Thus, we cannot draw direct links between institutional policies/practices and unit-level outcomes, nor do we seek to make inferences about the effectiveness of particular policies and practices. While no nationally representative dataset exists at that level of analysis, original data collection might enable future researchers to explain our curious “non-finding" regarding the (lack of) connection between women’s overall representation and their representation in CS&E. For now, we are left to conclude that interventions aimed at simply recruiting more women students to the institution overall are unlikely to produce “trickle down” effects in the form of more equitable representation for women in CS&E. Future data collection efforts to examine program/field-specific dynamics more closely will also advance insights derived from research by Correll (2017) and Ecklund et al. (2012) [17], [72].

By extension, one particularly consequential limitation of our study is that IPEDS lacks information on faculty gender composition by STEM field/unit. Because the representation of women tenure-track faculty in STEM fields is generally positively associated with the representation of women graduates in STEM fields [78], this IPEDS limitation likely leads us to underestimate the full impact of gendered faculty dynamics on the sex composition of degrees in these two heavily male-dominated fields.

As mentioned previously, IPEDS also lacks individual-level student data that could facilitate a multi-level analysis of this issue. Future studies should endeavor to combine IPEDS data with individual-level data from other nationally representative datasets, such as the National Survey of College Graduates, to facilitate multi-level modeling designed to assess the gendered experiences of students within institutions, and beyond the two fields examined here. Given the stunning explanatory power of just a handful of institutional variables tested here, advanced multi-level modelling could have significant potential to improve our ability to predict individual and aggregate-level outcomes.

Conclusions

Characteristics related to institutional type and sector explain a large proportion of the variation in the proportion of degrees women earn in CS&E fields. Moreover, institutional demographics matter: Institutions successful at serving historically marginalized groups in multiple dimensions (minorities, veterans) are also more successful at broadening participation in another dimension by increasing the proportion of CS&E degrees earned by women. Conversely, financial barriers experienced by first-generation and low-income students appear to lower women’s representation in CS&E, especially at institutions heavily reliant on Pell grants or tuition. Our analyses successfully identify additional institutional selectivity factors that positively impact women’s representation in engineering but not in computer science.

Our discussion explicitly links these observed patterns to classic concepts in sociology of organizations and education, specifically the idea that higher educational institutions are gendered organizations that play a key role in perpetuating “inequality regimes” [16]. We also outline the need for additional data collection and integration efforts to facilitate multi-level analyses of the combined effects individual, programmatic, and institutional characteristics have on gender disparities in STEM degrees -- including but not limited to CS&E. Furthermore, our discussion focuses on the implications for higher educational policy and institutions, which are generally charged with broadening participation in STEM fields [74], [77]. Finally, we also link our findings to recent research indicating a significant shift in public discourse about -- and in support of -- stronger public investments into higher education [69].

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