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The correlation between undergraduate student diversity and the representation of women of color faculty in engineering

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Abstract

Background: Despite the critical role of faculty diversity in the persistence and academic experiences of undergraduate students as well as in the development of engineering innovations, women of color (WoC) faculty are still underrepresented in engineering programs across the United States.

Purpose/Hypothesis: This study identifies whether the demographic composition of undergraduate engineering students is correlated with the representation of WoC faculty. It also highlights the institutional- and departmental-level factors that contribute to the race–gender diversification of the engineering professoriate.

Design/Method: Informed by organizational demography as the theoretical framework, the methods include linear and logit regression analyses. Data come from the American Society for Engineering Education, the Integrated Postsecondary Education Data System, and the American Community Survey, and include engineering departmental-level observations across 345 institutions over 12 years.

Results: Engineering departments that award more bachelor's degrees to women African American/Black undergraduate students are more likely to employ relatively more African American/Black women faculty. This positive relationship is also found among Asian Americans and Hispanics/Latinas.

Conclusions: Research findings demonstrate the relationship between engineering undergraduate composition, as well as other departmental- and institutional-level factors, and the prevalence of WoC faculty. The findings highlight important areas for stakeholders and academic administrators to consider when developing strategies and programs to diversify the composition of engineering faculty.

KEYWORDS

diversity, faculty, undergraduate, women

1 | INTRODUCTION

More than 40 years have passed since Malcom, Hall, and Brown (1976) and DeJoie (1977) called for a change in academic culture regarding gender and race, and noted that women faculty from certain racial/ethnic groups may experience a unique challenge of simultaneous sexism and racism, also known as the "double bind." The lack of women, particularly women of color (WoC), in the professoriate has been noted in the literature for decades, yet many academic departments in science, technology, engineering, and mathematics (STEM), particularly in engineering, still struggle with issues of underrepresentation. Engineering has been regarded as important to a nation's economic development, technological innovations, and national security; therefore, it is critical to address issues regarding the recruitment and retention of WoC faculty in this field (National Academy of Engineering, 2004). After all, engineering faculty play an important role in the education, experiences, and retention of undergraduate students in engineering majors and, subsequently, in the professional engineering workforce (Lichtenstein, Chen, Smith, & Maldonado, 2014).

Faculty members are integral to the experiences and academic outcomes of undergraduate students. In addition to serving as role models, mentors, instructors, and course developers, faculty fill other important roles critical to student academic and employment success (Bettinger & Long, 2005; Bjorklund, Parente, & Sathianathan, 2004; Umbach & Wawrzynski, 2005). Rask and Bailey (2002) found that women and underrepresented racially minoritized (URM) faculty serve as role models for women and URM students, and that taking courses from faculty more "like you" can positively facilitate women and racially minoritized students' college major choice following their role models. Given that previous studies have shown a strong relationship between faculty diversity and the academic success of students, we examine whether institutions are diversifying their faculty to meet the needs of their student populations. That is, we examine how relative representation of undergraduate students, organizational demography (Kanter, 1977), is related to the prevalence of WoC faculty.

We conduct a series of regression analyses to identify whether organizational demography, the demographic composition of undergraduate engineering students, is correlated with the representation of WoC faculty by addressing the following research questions:

1. What is the correlation between a diverse engineering undergraduate population and a higher representation of WoC faculty?
2. Among engineering departments that did not employ any WoC faculty in 2005, which institutional and departmental factors are associated with subsequent diversification of the faculty?

We contribute to the engineering education literature by extending the quantitative research on WoC faculty in engineering. Due to the lower numbers of WoC faculty in general across institutions, some datasets mask the numbers of WoC faculty in order to preserve individual anonymity. Only a few datasets can be used to examine the issues associated with the underrepresentation of WoC faculty in engineering. However, a number of efforts are underway to improve data availability regarding the representation of WoC faculty in STEM fields, such as the Nelson Diversity Survey (NDS) on the diversity of science and engineering faculty at research universities (Nelson, 2017). The NDS dataset provides counts and percentages of faculty by gender, race, and faculty rank within the top 100 U.S. departments across 15 disciplines/subdisciplines, including engineering. Here, we use the dataset from the American Society for Engineering Education (ASEE), given its focus on the demographic composition of engineering students and faculty. The ASEE, a professional society, has annually collected departmental-level demographic information on students and faculty from its 345 member institutions (ASEE, 2018). The ASEE database provides counts of WoC faculty yearly by department and institution, providing an opportunity to examine departmental factors related to the prevalence of WoC faculty. In this study, we leverage the departmental-level data from ASEE, which include the numbers of WoC faculty by engineering department and institution, and merge it with data from the Integrated Postsecondary Education Data System (IPEDS; U.S. Department of Education, National Center for Education Statistics [NCES], 2018) and the American Community Survey (ACS). From IPEDS, we analyze the role of institutional characteristics—such as Carnegie classification, level of urbanicity, and whether the institution is public or private—in the diversity of engineering faculty, as well as the departmental-level WoC undergraduate student completions, whereas ACS provides the demographic composition of residents by state.

Our research findings contribute to the understanding of how institutional- and departmental-level factors, such as undergraduate student diversity, are correlated with faculty diversity in engineering. Disaggregating ASEE's data by gender and race/ethnicity and merging data with IPEDS and ACS allows for a unique opportunity to investigate the underrepresentation of WoC in engineering to reveal essential foundational and contextual information for further studies and development of potential interventions. Research findings provide academic administrators and stakeholders with evidence that could be used to develop strategies to increase the participation and retention of WoC faculty and to transform academic culture to address issues associated with the double bind.

2 | BACKGROUND

2.1 | Racial and gender diversity in engineering

Diversity has increasingly become an important research area in engineering education, with conversations largely focusing on undergraduate students. Engineering education venues have highlighted issues associated with a lack of diversity in engineering among undergraduate students (Foor & Shehab, 2009; Griffith & Main, 2019; Litzler, Samuelson, & Lorah, 2014; Long & Mejia, 2016; Main & Schimpf, 2017; Martin, Simmons, & Yu, 2013; May & Chubin, 2003; Reichert & Absher, 1997; Trenor, Yu, Waight, Zerda, & Sha, 2008; Trytten, Lowe, & Walden, 2012). Previous literature has shown that women and African American/Black or Hispanic/Latina students apply to engineering programs at lower rates than their counterparts, and among those who pursue engineering degrees, their retention rate is also lower than their counterparts' (ASEE, 2017; Malicky, 2003). Johnson and Sheppard (2004) considered the lower application and retention rates to be major contributing factors to the challenges associated with meeting the national demand for a larger and well-qualified engineering workforce (National Science Foundation, 2018). Related to these lower application and retention rates, only approximately 20% and 5% of engineering degrees are awarded to women students and African American/Black students, respectively (National Science Foundation, 2018).

Studies on diversity among faculty tend to focus on STEM disciplines rather than engineering specifically. Among studies investigating the representation of WoC faculty, researchers have found that in addition to struggles associated with the double bind (Armstrong & Jovanovic, 2015; Berry, Cox, & Main, 2014; DeJoie, 1977; Sánchez-Peña, Main, Sambamurthy, Cox, & McGee, 2016), WoC faculty also face issues associated with the “leaky pipeline” (Bilimoria, Joy, & Liang, 2008); “chilly climate,” covert and overt “microaggressions” (Hess, Gault, & Yi, 2013; McGee & Bentley, 2017; Trower, 2002); and the “minority tax” (Armstrong & Jovanovic, 2017; Coe, Wiley, & Bekker, 2019). In terms of faculty recruitment of women, the literature is mixed. Research by Williams and Ceci (2015) showed that women have an advantage in placement in academic science careers. This finding is also supported by Way, Larremore, and Clauset (2016). Overall, Ceci (2018) asserted that “the evidence supporting the view that hiring bias is not the source of women's underrepresentation … comes from both correlational (hiring audits) and experimental studies” (p. 27). However, after hiring and recruitment, a number of studies have found threats to persistence and success for STEM WoC faculty, including a lack of mentoring (Bilimoria et al., 2008; Blackwell, 1989; McGee, 2018; Myers & Turner, 2004; Zellers, Howard, & Barcic, 2008), tokenism (Padilla & Chávez, 1995; Parson, Sands, & Duane, 1992; Turner & González, 2011), pioneerism (e.g., being the first racially minoritized or woman racially minoritized professor in a department; Etzkowitz, Kemelgor, & Uzzi, 2000; Fleming, 2008), and “pet-to-threat” syndrome (e.g., WoC first welcomed can be turned against; Hess et al., 2013; Thomas, Johnson-Bailey, Phelps, Tran, & Johnson, 2013).

In the following sections, we discuss why faculty diversity matters and then articulate the evidence from the literature examining how academic institutional factors could contribute to the relative representation of WoC faculty in engineering. Partially due to data availability, these studies are few and sparse. Thus, our study addresses this important gap in identifying how institutional factors, including student demographic composition, contribute to diversity in the professoriate using data merged from ASEE, IPEDS, and ACS.

2.2 | Why faculty diversity matters

The demographic composition of faculty is important because a diverse faculty workforce can (a) yield more diverse ideas and solutions to solve today's 21st century engineering STEM problems (National Academy of Engineering, 2004; Ohland et al., 2008); (b) help attract and retain other diverse faculty and students (Main, 2014, 2018; Schrader, Callahan, & Moll, 2006); (c) provide a larger pool of diverse role models to help reduce feelings of isolation, increase retention, provide buffers against racism and discrimination, enhance performance, and so on, among students and other faculty (Ong, Wright, Espinosa, & Orfield, 2011; Rask & Bailey, 2002); and (d) help advance social justice efforts. Many studies that focus on diversity at the professoriate level emphasize the experiences of women in general rather than those of WoC specifically (for exceptions, see DeCuir-Gunby, Grant, & Gregory, 2013). However, intersectionality theory proposes that the experiences at the intersection of gender and race/ethnicity encompass a struggle against racially minoritized status in more than one area (Collins, 1993; Crenshaw, 1989).

As faculty members of the engineering field, WoC faculty have made substantial contributions as knowledge makers, theory builders, innovators, and leaders (Alfred, Ray, & Johnson, 2019; Barabino, 2019; Hoh, 2007). In addition to their major contributions to the engineering field, WoC also contribute to improving recruitment and retention efforts in engineering programs. Specifically, WoC faculty members can serve as role models for students, thereby helping science and engineering departments recruit and retain women and URM students (Main, 2018; Price, 2010; Rask & Bailey, 2002; Robst, Keil, & Russo, 1998; Sonnert, Fox, & Adkins, 2007). As role models, WoC faculty members may help mitigate undergraduate and graduate students' own doubts about belonging and identity (Ong et al., 2011). A more diverse faculty can also provide a wider range of curricular and pedagogical choices to appeal to URM students than the traditional curriculum might attract (Henes, Bland, Darby, & McDonald, 1995; Naphan-Kingery, Ridgeway, Brockman, McKane, & Botchway, 2019; Schrader et al., 2006).

Therefore, by extension, having more WoC faculty members who help improve the retention of WoC students can also contribute to diversifying the engineering profession. This indirect benefit from academia to postgraduation employment outcomes is important for several reasons. First, from the perspective of increasing the overall number of trained engineers in the workforce, losing fewer engineering students due to the perception that they may not fit in or identify with their surroundings would lead to a comparatively larger STEM workforce (Steele et al., 2007; Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development, 2001; Dasgupta & Stout, 2014). Second, a more diverse engineering workforce generates several positive outcomes for individual businesses and the profession writ large (Chubin, May, & Babco, 2005; Kochan et al., 2003; Robinson & Dechant, 1997). Third, a more diverse population of engineers may also lead to better outcomes in professional engineering projects, such as more effective design teams and improved cultural competency among team members (Groves & Feyerherm, 2011; Kochan et al., 2003; Main & Wang, 2020). Thus, increasing the participation of WoC in the professoriate can also contribute to a more diverse engineering workforce.

From the perspective of an organization, a diverse engineering faculty has the potential to improve the overall functioning of departments. A diverse faculty helps bolster future faculty recruiting efforts in a positive feedback loop, wherein a more diverse faculty can be more attractive to potential URM PhD candidates (Bernadin & Atuahene, 2007). As well, a diverse faculty in the department can enhance mentoring and network availability for new WoC faculty members, mitigating psychological stress including the "imposter syndrome"; this has been shown to improve organizational diversification efforts (Kalev, Dobbin, & Kelly, 2006; Williams, Thakore, & McGee, 2016; Zambrana et al., 2015; Zellers et al., 2008). Moreover, just as diverse teams in business settings may lead to more positive outcomes, increasing the number of women faculty members may similarly improve the functioning of engineering departments (Joshi, 2014).

2.3 | Institutional-level factors and faculty diversity

In this section, we synthesize research findings regarding the role of institutional-level factors on the prevalence of WoC in the professoriate. Previous studies have found institutional characteristics—such as the type of institution (public or private), research intensity, Historically Black Colleges and Universities (HBCU)—matter in terms of the composition of faculty. Compared to other types of academic institutions, HBCUs are more likely to have higher proportions of Black faculty (Berry et al., 2014; Kulis, Chong, & Shaw, 1999). Public institutions and institutions that receive federal funding are associated with more diversified faculty compositions (Bach & Perrucci, 1984; Kulis et al., 1999). Su and Gaughan (2014) also found that research institutions that invest more in creating structures addressing the needs of women faculty are more likely than other institutions to have higher proportions of women faculty. However, top science and engineering research universities are less likely than 4-year colleges and other types of postsecondary institutions to employ women and African American/Black or Hispanic/Latina faculty (Beutel & Nelson, 2006; Kulis, 1998; Kulis et al., 1999; National Research Council, 2001). More selective institutions and institutions with higher expenditures per student are associated with fewer women or URM faculty (Bach & Perrucci, 1984; Szafran, 1984; Tuitt, Sagaria, & Turner, 2007).

The urbanicity of an institution also matters for the recruitment and retention of faculty. An institution's proximity to a large urban area tends to be associated with higher faculty diversity (Bach & Perrucci, 1984; Eddy, 2007). Other aspects of the institution's geographic location can also affect faculty diversity; for example, several studies focusing on Black scientists found that Black faculty are more likely to work at institutions located in the southern states of the United States, likely correlated with HBCUs (Kulis et al., 1999; Modica & Mamiseishvili, 2010). In a study on faculty recruitment and retention in community colleges, Eddy (2007) argued that with a more diverse student body, urban colleges are faced with a stronger need to increase faculty diversity compared to rural colleges. Accordingly, we examine whether the composition of engineering undergraduates is correlated with faculty diversity using Kanter's (1977) organizational demography as our theoretical framework.

3 | THEORETICAL FRAMEWORK

3.1 | Organizational demography

Organizational demography theory proposes that the culture, climate, and circumstance within an organization can be affected by the differential representation of social groups (Kanter, 1977; Wharton, 1992; Zucker, 1987). To exemplify, Kanter (1977) argued that when there are few women within an organization, they will be viewed as "tokens" or "outsiders," such that women will be isolated and excluded from core positions and have limited access to opportunities or promotions. However, Kanter's (1977) theory also predicts that negative organizational climate and culture against women will abate as the proportion of women increases within the organization. Previous studies have found results consistent with the theory of organizational demography. In particular, Kanter (1977) found that the proportions of women managers are positively correlated with the proportions of women employees, whereas Zweigenhaft (1987) found that the proportions of African American managers are positively associated with the proportions of African American employees. Similar empirical evidence has been found in municipal governments (Saltzstein, 1986) and academic institutions (Ehrenberg, Jakubson, Martin, Main, & Eisenberg, 2012; Main, 2018). Main (2018), for example, found that women are more likely to complete their PhDs in science and engineering departments that have higher proportions of women faculty.

Consistent with organizational demography theory, previous studies have found that changing the composition of an academic department can help alter its culture and potentially overcome a status quo that may have been relatively unwelcoming under conditions of lower diversity (Callister, 2006; Fox, 2010; McGee, in press; Settles, Cortina, Malley, & Stewart, 2006). Not only have previous studies shown that a diverse faculty composition can help increase the diversity of the student body, but evidence also indicates that more diverse student populations may attract more diverse faculty. For example, Kulis et al. (1999) found that institutions with a larger and more diverse student body tend to employ a higher percentage of Black faculty. The consensus from the literature is that a more diverse student composition is correlated with a more diverse faculty composition (Bach & Perrucci, 1984; Beutel & Nelson, 2006; Kulis et al., 1999; Myers & Turner, 2004). Thus, we anticipate this to also be the case in engineering, and we apply Kanter's organizational demography as a framework to examine whether the prevalence of WoC undergraduate engineering students is correlated with the representation of WoC engineering faculty. In addition, we take into account important institutional-level factors described in the literature review to provide a more comprehensive understanding of how organizational factors and structures are associated with faculty diversity.

3.2 | Intersectionality theory and defining WoC

Many researchers and professional organizations tend to define WoC as women who did not identify as White in regard to race/ethnicity (Comas-Díaz & Greene, 1994; Gutierrez, 1990; Ong et al., 2011; Towns, 2010; Turner, 2002). In this study, we define WoC as women who reported in the ASEE database as African American/Black, Hispanic/Latina, Asian American or other race/ethnicity. Although previous studies do not consider Asian Americans as an underrepresented group in academia or as a marginalized group, we include Asian Americans in our study of WoC engineering faculty because their experiences do not mirror those of their White colleagues (Sambamurthy, Main, Sanchez-Peña, Cox, & McGee, 2016). Malcom and Malcom (2011), for example, stated that "it is also clear that Asian-American women face challenges to advancement and recognition that resemble the challenges of URM women" (p. 169). Furthermore, Wu and Jing (2011) have shown that Asian American women are underrepresented in full professor ranks and academic leadership roles when compared to URM women faculty.

Through the lens of intersectionality theory, WoC faculty experience unique circumstances that arise from the intersection of their race and gender, among a myriad of other characteristics that differentiate their experiences (Collins, 1993; Crenshaw, 1989). Intersectionality theory has been used to study WoC experiences in a broad spectrum of disciplines such as psychology, political science (Verloo, 2006), sociology (Choo & Ferree, 2010), health (Bauer, 2014), and education (Museus & Griffin, 2011), to name a few. More specific to our study, within the context of STEM education, researchers have used the framework to examine a broad array of issues. For example, Wilkins-Yel, Hyman, and Zounlome (2019) applied intersectionality theory to understand the experiences of WoC graduate students in STEM disciplines when they are exposed to microaggressions. Kvasny, Trauth, and Morgan (2009) framed their work on the intersection of class, gender, and race and how it shapes the experiences of Black women students and learners in information technology. Ro and Loya (2015) used intersectionality theory to frame the effects of race and gender on engineering students' self-reported learning outcomes. In the context of our study, intersectionality theory informs our investigation by highlighting the importance of both gender and race in organizational demography.

4 | DATA

We collected our data from ASEE (2018), IPEDS, and ACS, focusing on engineering departments in the 345 ASEE member institutions from 2005 through 2016. The ASEE dataset includes both self-reported data from accredited institutions and faculty demographic information at the department level and is sufficiently large enough to disaggregate analyses by faculty gender and race/ethnicity. Although the ASEE database has reliable faculty demographic information, it has few variables regarding institutional characteristics. Therefore, we supplemented the ASEE dataset with data collected from IPEDS (NCES, 2018). We also use the departmental-level student completion data from IPEDS because of its longer time horizon (the ASEE dataset does not distinguish student completion data by the intersection of gender and race/ethnicity before 2005). Based on our literature review of the institutional-level factors correlated with faculty diversity, we include the following variables: whether the institution is private or public, the Carnegie institution classification, level of urbanicity, and HBCU status. We consider two measures of engineering student composition: (a) WoC enrollment; and (b) WoC degree completion. In addition, we measure the representation of WoC faculty in two ways: (a) the count of WoC by engineering department and (b) employment of engineering WoC faculty among programs that did not report any WoC faculty in 2005. Finally, we also control for state-level demographic composition of residents using information collected from the ACS (Ruggles et al., 2019).

The descriptive statistics of our analytic sample are presented in Table 1. The unit of observation in Table 1 is at the engineering department by year level, including all engineering departments within the 345 ASEE membership institutions from 2005 to 2016. These ASEE membership institutions are only a subset of all engineering programs in the United States, and there are relatively more Research I (26%) and Research II (24%) institutions compared to the numbers present nationwide. Additionally, comparatively fewer HBCUs (3%) are in the ASEE dataset, and most ASEE institutions are in city/suburban areas (83%). Despite these differences in terms of institutional-level characteristics between our analytic sample and the national sample, the gender and racial/ethnic compositions of engineering faculty in our analytic sample are consistent with those reported by the National Science Foundation (2017). The National Science Foundation (2017) reports that in 2016, 15% of engineering faculty were women, and 3% Black/African American, 6% Hispanic/Latinx, and 32% Asian American. Similarly, the ASEE dataset reports that approximately 14% of engineering faculty were women, and 3% African American/Black, 4% Hispanic/Latinx, and 24% Asian American. Among women engineering faculty in the ASEE dataset, 4% are African American/Black, 5% Hispanic/Latina, and 23% Asian American.

Based on the data from ASEE, not all 345 academic institutions had at least one WoC faculty in engineering during the time period of our investigation (from 2005 to 2016). In Figure 1, we show the proportion of engineering departments with at least one WoC engineering faculty represented by racial/ethnic group during this time period. Figure 1 shows the trends of representation by race/ethnicity. We observe that many of the engineering departments did not have any WoC faculty in 2005, but as time progresses, more departments employed at least one WoC faculty. Despite this growing trend, many engineering programs still did not have any women African American/Black or Hispanic/Latina engineering faculty in 2016. For example, in 2016, 91% of engineering departments still did not have any African American/Black women engineering faculty.

TABLE 1 Descriptive statistics

	Proportion
Institutional-level characteristics	
Private institution	0.371
Research I institution	0.258
Research II institution	0.238
All other institutions	0.504
HBCU	0.029
City	0.638
Suburban	0.194
Town	0.136
Rural	0.032
Departmental-level characteristics	
Engineering undergraduate degree completion	
Women	0.187
African American/Black	0.061
Asian American	0.073
Hispanic/Latino	0.066
White	0.519
Other race/ethnicity or nonresident alien	0.280
Average number of engineering undergraduate degrees awarded	60.7
Demographic composition of *all* engineering faculty	
Women	0.135
African American/Black	0.025
Asian American	0.243
Hispanic/Latino	0.036
White	0.629
Other race/ethnicity or nonresident alien	0.067
Average number of faculty	18.1
Demographic composition of *women* engineering faculty	
African American/Black	0.035
Asian American	0.233
Hispanic/Latina	0.048
White	0.609
Other race/ethnicity or nonresident alien	0.075
Average number of women faculty	2.4

Note: Our ASEE sample consists of engineering departments in each of the 345 ASEE institutions. Observations with missing values are omitted from the summary statistics; calculations are on a variable-by-variable basis.

5 | METHODS

Our analytical approach is summarized in Figure 2, which highlights the institutional- and departmental-level factors that we examine for correlation with the representation of WoC faculty in engineering. Below, we discuss our methods for addressing each of our research questions and provide additional details regarding our variables of interest.

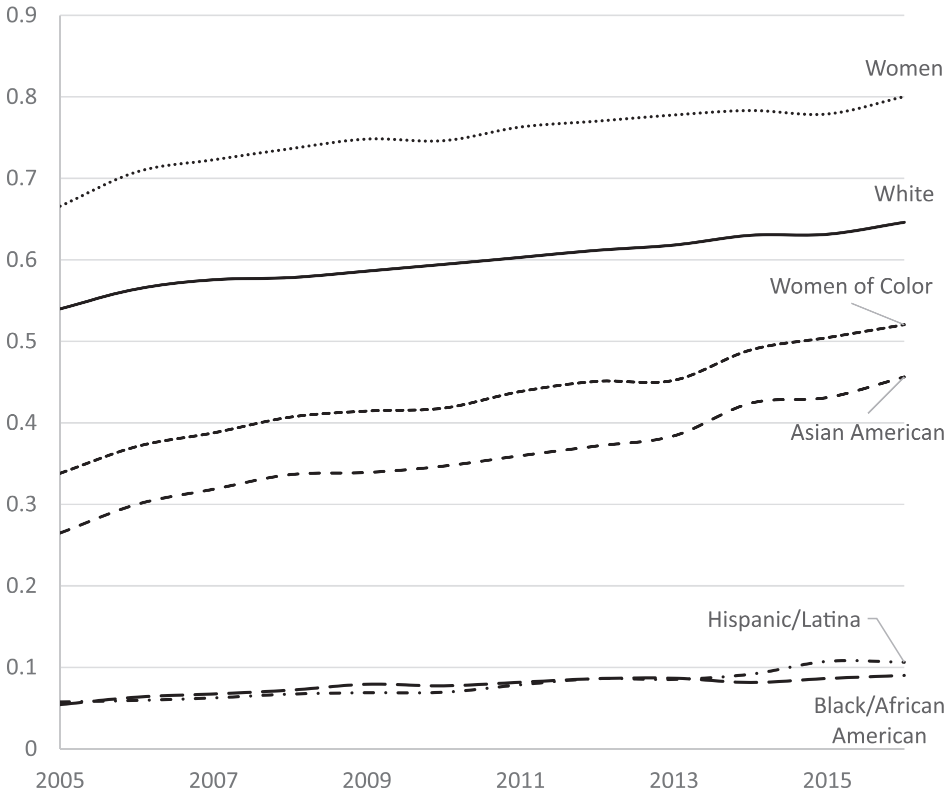

FIGURE 1 Proportion of engineering departments with at least one woman engineering faculty by race/ethnicity from 2005 to 2016

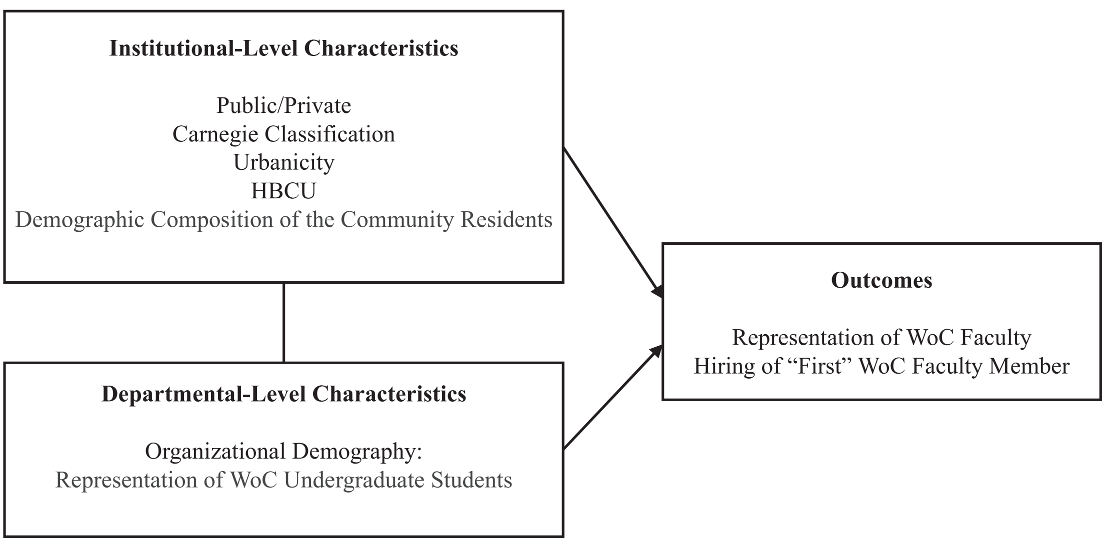

FIGURE 2 Conceptual model of factors correlated with the representation of women of color (WoC) faculty

5.1 | Research Question 1: Linear regression analysis

What is the correlation between a diverse engineering undergraduate population and a higher representation of WoC faculty?

We used linear regression analyses to investigate the correlation between the demographic composition of engineering undergraduate students and the representation of WoC faculty. Because the double bind and intersectionality theory (Armstrong & Jovanovic, 2015; Collins, 1993; DeJoie, 1977) explain that the experiences of WoC vary at the intersection of gender and race/ethnicity, we expect that the prevalence of African Americans/Blacks, Asian Americans, and Hispanics/Latinas may also be related differently to institutional and departmental factors. Therefore, we run a separate regression for each racial/ethnic group, as well as for all WoC and for all women engineering faculty combined. The regression equation is as follows:

$$p_{ijt} = \lambda_t + \gamma_j + \mathrm{IC}_i + \mathrm{DC}_{ijt} + R_{it} + \varepsilon_{ijt}. \tag{1}$$

In Equation (1), we use i to denote an institution, j to denote an engineering department, and t to denote a given year. For each disaggregated regression form, p_{ijt} denotes the count of African American/Black, Asian American, or Hispanic/Latina women engineering faculty. For the aggregated regression form, p_{ijt} denotes the count of WoC engineering faculty. We let λ_t and γ_j denote the year fixed effect and engineering department fixed effect, respectively. Because of the large number of available engineering departments, we keep only the largest departments that consist of at least 5% of total engineering faculty population (biomedical, chemical, civil, electrical/computer, and mechanical engineering), and the other smaller engineering departments (aerospace, architectural, biological/agricultural, environmental, industrial/manufacturing systems, metallurgical/material, mining, nuclear, petroleum engineering, and engineering management) are combined into a single category of general/other engineering. We let IC_i denote the time invariant institutional characteristics of institution i, including (a) whether the institution is private, (b) the Carnegie classification of the institution (Research I institution, Research II institution, or all other institutions), (c) whether the institution is an HBCU, and (d) level of urbanicity. Level of urbanicity is determined through a methodology developed by the U.S. Census Bureau's Population Division in 2005, and it has four levels: city, suburban, town, and rural. While we include HBCU designation in our models, we do not include indicators for other Minority Serving Institutions (MSI), such as Hispanic-Serving Institutions (HSI). HSIs, for example, are defined as institutions with larger than 25% Hispanic undergraduate student enrollment. Therefore, rather than using the HSI indicators, we instead directly measure engineering undergraduate enrollment by gender and race/ethnicity.

The average departmental-level characteristics are denoted by DC_{ijt}, which include the counts of (a) all women faculty; (b) African American/Black, Asian American, and Hispanic/Latina women engineering bachelor's degree completions; and (c) total number of bachelor's degree completions. These counts are all evaluated at institution i, engineering department j, and year t. We also control for the demographic composition of residents in the state where institution i is located at time t, which is denoted by R_{it}. Finally, ε_{ijt} is the error term, which is clustered at the institution by engineering department level to account for within-institution and engineering department correlation in error terms. Our regression models also include missing indicators for variables containing missing observations although the missing dummy variables are not shown in Equation (1). Note that our results are qualitatively unaffected when all missing information is excluded.

We consider two measures of engineering student composition: (a) WoC enrollment and (b) WoC degree completion. Again, we include measures that disaggregate by race/ethnicity—African Americans/Blacks, Asian Americans, and Hispanics/Latinas—because intersectionality theory suggests that the experiences of WoC can differ at the intersection of gender and race/ethnicity. We also run separate models that use measures aggregating all WoC undergraduate students as a comparison. Because it can take time for institutions to hire new faculty in response to changes in the demographic composition of their student population, we use lagged variables to measure student demographic composition. The lagged variables are the numbers of African American/Black, Asian American, and Hispanic/Latina engineering students completing their bachelor's degrees the year in consideration of faculty prevalence. Although time to degree varies, 4 years is considered a common completion time for a bachelor's degree (Miller, 2010; U.S. Department of Education, NCES, 2017), and thus, this is a proxy measure for WoC student enrollment from 4 years before the relative year considered in the outcome variable (prevalence of WoC faculty). This approximate 4-year lag reasonably allows for engineering programs to respond to demographic changes in their first-year engineering student cohort. Since the hiring response time can vary and some institutions also consider 6 years as typical for time to degree, we also conduct a series of robustness checks. We run our models with advanced or delayed ($\pm$3 years) completion variables, and our findings are qualitatively similar in every case. As an additional robustness check, we also conduct analysis using the undergraduate enrollment variables, rather than the completion variables, and our results are qualitatively similar (although not shown in the Results section).

With Equation (1), we process our panel data with the pooled ordinary least-squared (OLS) regression framework instead of an institutional-level fixed effect model. In general, fixed effect models work well with panel data and may be less subject to endogeneity bias because they use only within-institution variation to estimate the parameters of interest. However, one limitation of the fixed effect model is that it cannot be used to estimate the time-invariant institutional-level characteristics, which constitute an important part of our research objectives. Consequently, following similar research studies in the literature (Oshio, Tsutsumi, & Inoue, 2015), we use the pooled OLS model as our main empirical approach to estimate the coefficients of the time-invariant variables.[1]

Furthermore, to complement our primary regression settings and to check the robustness of our research design, we exclude the time-invariant institutional-level characteristics from our regression model and re-estimate it with an institutional-level fixed effect setting, as shown in the following regression form:

$$p_{ijt} = \lambda_t + \gamma_j + \delta_i + \mathrm{DC}_{ijt} + R_{it} + \varepsilon_{ijt}. \tag{2}$$

Compared to Equation (1), the only difference we make in Equation (2) is to replace time-invariant institutional-level characteristics, IC_i, with institutional-level fixed effect terms, δ_i. Again, we estimate our model with errors clustered at the institution by engineering department level.

5.2 | Research Question 2: Logit regression

Among engineering departments that did not employ any WoC faculty in 2005, which institutional and departmental factors are associated with subsequent diversification of the faculty?

We also investigated the institutional and engineering departmental factors that may be associated with the subsequent or eventual hiring of at least one WoC faculty. Since our data spans from 2005 through 2016, we used data from 2005 to identify departments that did not employ any WoC faculty. Among departments that did not employ at least one WoC faculty in 2005, we then identified whether the department hired WoC faculty at any point between 2005 and 2016. Because we do not incorporate data prior to 2005, we are unable to confirm whether the department may have employed a WoC prior to 2005 but did not have a WoC in the engineering faculty in the year 2005 specifically. To identify the factors that contribute to diversification, we first classified the engineering departments into three categories: (Type 1) no WoC engineering faculty from 2005 through 2016; (Type 2) no WoC engineering faculty in 2005, but hired at least one WoC faculty between 2006 and 2016; and (Type 3) already employed a WoC engineering faculty in 2005.

To compare the characteristics of Type 1 and Type 2 engineering departments, we use logit regression. That is, we exclude Type 3 departments from the sample, set Type 1 departments as the baseline, and compare the relative characteristics of Type 2 departments versus Type 1 departments. The regression form is as follows:

$$T_{ij} = \gamma_j + \mathrm{IC}_i + \varepsilon_{ij}. \tag{3}$$

In Equation (3), the dependent variable T_{ij} denotes the type of engineering program j in institution i, and the control variables are similarly denoted as those in Equation (1). Again, we estimated this equation with the number of all women aggregated, as well as disaggregated by race/ethnicity: African American/Black, Hispanic/Latina, and Asian American. Due to the nature of this analysis, we examine only 1 year of institution by engineering department observations. This means we have less variation within the dataset to identify our regression parameters; that is, we can compare engineering departments against one another, but we can no longer compare the same engineering department across years. Furthermore, to avoid multicollinearity issues, we exclude the departmental-level characteristics from our regression model. We instead show the impact of these departmental-level variables by tabulating the ratio of average departmental-level characteristics at Type 2 engineering departments over Type 1 engineering departments by race/ethnicity.

6 | RESULTS

6.1 | Linear regression analysis

We used linear regression analysis to examine the associations between institutional and departmental factors and the prevalence of WoC faculty. Our results are presented in Table 2—aggregated with all women faculty (Column 1) and all WoC faculty (Column 2) as well as disaggregated by race/ethnicity: African American/Black, Asian American,

TABLE 2 Linear regression: Institutional and engineering departmental factors and the counts of women of color engineering faculty

	Women engineering faculty					
	1 All women	2 All women of color	3 African American/ Black	4 Asian American	5 Hispanic/ Latina	6 White
Institutional-level characteristics						
Private Institution	0.144***	−0.103***	0.000	−0.122***	0.019***	0.236***
	(0.008)	(0.005)	(0.002)	(0.004)	(0.003)	(0.007)
Research II Institution	−0.008	0.066***	−0.004**	0.043***	0.028***	−0.085***
	(0.010)	(0.006)	(0.002)	(0.005)	(0.003)	(0.009)
All Other Institutions	0.334***	0.154***	0.012***	0.071***	0.071***	0.178***
	(0.010)	(0.006)	(0.002)	(0.005)	(0.003)	(0.009)
HBCU	0.094***	0.521***	0.458***	0.057***	0.007	−0.463***
	(0.026)	(0.016)	(0.005)	(0.013)	(0.008)	(0.023)
Suburban	0.286***	0.130***	−0.021***	0.118***	0.033***	0.198***
	(0.009)	(0.006)	(0.002)	(0.005)	(0.003)	(0.008)
Town	−0.019	−0.063***	−0.024***	−0.069***	0.030***	0.053***
	(0.012)	(0.007)	(0.002)	(0.006)	(0.004)	(0.010)
Rural	−0.037*	0.055***	0.012***	−0.046***	0.089***	−0.192***
	(0.022)	(0.013)	(0.004)	(0.011)	(0.007)	(0.019)
Engineering department fixed effect						
Biomedical Engineering	1.022***	−0.004	0.014***	−0.102***	0.084***	0.966***
	(0.016)	(0.010)	(0.003)	(0.008)	(0.005)	(0.014)
Chemical Engineering	0.646***	−0.084***	0.017***	−0.245***	0.144***	0.676***
	(0.014)	(0.008)	(0.003)	(0.007)	(0.004)	(0.012)
Civil Engineering	0.522***	−0.208***	0.007***	−0.284***	0.069***	0.695***
	(0.012)	(0.008)	(0.002)	(0.006)	(0.004)	(0.011)
Mechanical Engineering	−0.089***	−0.257***	−0.008***	−0.296***	0.047***	0.129***
	(0.012)	(0.007)	(0.002)	(0.006)	(0.004)	(0.010)
General/other Engineering	0.588***	−0.192***	−0.005**	−0.298***	0.112***	0.696***
	(0.011)	(0.007)	(0.002)	(0.006)	(0.003)	(0.009)
Average departmental-level characteristics (in 100 units)						
Faculty Count	13.825***	3.927***	0.398***	2.804***	0.725***	8.574***
	(0.028)	(0.017)	(0.006)	(0.014)	(0.009)	(0.024)
African American/Black Women Engr Bachelor's Degree Completion	1.869***	3.817***	3.209***	1.821***	−1.213***	−0.232
	(0.268)	(0.165)	(0.053)	(0.137)	(0.085)	(0.232)
Asian American Women Engr Bachelor's Degree Completion	3.408***	−0.897***	−0.094***	0.133*	−0.936***	3.467***
	(0.136)	(0.083)	(0.027)	(0.069)	(0.043)	(0.117)
Hispanic/Latina Women Engr Bachelor's Degree Completion	4.843***	8.104***	0.247***	−0.389***	8.246***	−2.549***
	(0.139)	(0.085)	(0.028)	(0.071)	(0.044)	(0.120)
Total Engr Bachelor's Degree Completion	−0.103***	−0.074***	0.021***	−0.022***	−0.073***	0.104***
	(0.008)	(0.005)	(0.002)	(0.004)	(0.003)	(0.007)
N	16,466					

Note: Models are specified as linear models. Standard errors clustered at institution by engineering departmental level are reported in parentheses. The sample used for these regressions includes all engineering department by year observations. Year fixed effects are included in the regression, but are not shown in this table. The omitted group for engineering department is Electrical/Computer Engineering and City for level of urbanicity. The coefficients associated with the percentage of women of color (WoC) residents by state are not shown.
***, **, and * denote significance levels .01, .05, and .10, respectively.

Hispanic/Latina, and White (Column 3 through Column 6, respectively). We focus on the results from Columns 2 through 5 in line with the purpose of this paper and provide Columns 1 and 6 for reference. The regression coefficients in each row are the marginal effects for the corresponding variable, and the standard errors clustered at the institution by departmental level are shown in parentheses.

We found that institutional and departmental characteristics matter in terms of the prevalence (or the number) of WoC faculty aggregated (Table 2, Column 2). Institutions that are public, HBCU, in suburban areas and are not Research I institutions are more likely than other types of institutions to have a higher number of WoC faculty. For example, our estimates indicate that compared to non-HBCU institutions, HBCU institutions are associated with a 0.52 increase in the count of WoC engineering faculty even after conditioning on other factors. Moreover, electrical/computer engineering, as well as engineering departments with more women African American/Black and Hispanic/Latina undergraduate engineering degree completions, tend to have higher counts of WoC faculty. Although these findings are largely consistent with previous studies, our study confirms that all of these factors are important even when they are measured together in one comprehensive model.

In terms of student characteristics, our study also highlights the significant positive relationship between women engineering bachelor's degree completions and prevalence of WoC faculty. A 100 increase in the count of women African American/Black and Hispanic/Latina undergraduate degree completions is associated with an increase of WoC faculty counts by 3.8 and 8.1, respectively. Columns 3 through 6 in Table 2 show our models for the disaggregated counts of African American/Black, Asian American, Hispanic/Latina, and White women faculty in engineering. Consistent with organizational demography, women African American/Black engineering faculty are more prevalent at institutions with higher women African American/Black engineering undergraduate degree completions. Also, more African American/Black women faculty members are at institutions that are HBCUs, in rural areas, and in chemical engineering departments compared to other engineering departments. Notably, conditioning on other variables, HBCU institutions are associated with a 0.46 higher count of African American/Black women engineering faculty compared to other institutions. Institutions with higher counts of Asian American women engineering faculty tend to be public institutions, neither Research I nor Research II institutions, and in suburban areas. Again, consistent with organizational demography, engineering departments with higher counts of Asian American women faculty also tend to have higher counts of Asian American women engineering bachelor's degree completions. Meanwhile, institutions with higher counts of women Hispanic/Latina engineering faculty also have higher degree completions among Hispanic/Latina bachelor's degree completions.

Our findings highlight the importance of the WoC undergraduate degree completions as theorized in organizational demography. Counts of WoC engineering faculty are strongly and significantly associated with counts of women bachelor's degree completions within the same racial/ethnic group, but generally not with counts of other racial/ethnic groups. For example, a 100 increase in the count of Hispanic/Latina women engineering completions is associated with an 8.2 increase in the count of Hispanic/Latina women engineering faculty. In contrast, the cross-race/ethnicity associations between faculty and completions are quite small and mostly practically insignificant relative to the associations within the same racial/ethnic group. The strongest cross-race/ethnicity association is 1.8, which is between the count of African American/Black undergraduate engineering degree completions and the count of Asian American women faculty.

In Table 3, we report the regression coefficients with institutional-level fixed effects. In general, our findings are qualitatively similar for the departmental-level characteristics, providing additional evidence that organizational demography matters in the prevalence of WoC faculty in engineering. To provide further evidence, we also investigated an alternative set of models where we merged the three undergraduate degree completion variables. In these models, we also found that the count of WoC undergraduate degree completion is positively correlated with more WoC faculty in engineering. This association is particularly strong for women Hispanic/Latina faculty.

6.2 | Logit regression

Our results from the logit regressions estimating the likelihood that an engineering department will employ a WoC faculty are presented in Table 4. Similar to the linear regression analyses in Table 2, we ran separate regressions for each race/ethnicity in Columns 3 through 6. As introduced previously, we divided engineering departments into three types: (Type 1) no WoC engineering faculty from 2005 through 2016; (Type 2) no WoC engineering faculty in 2005, but

TABLE 3 Linear regression: Institutional and engineering departmental factors and the counts of women of color engineering faculty

	Women engineering faculty					
	1	2	3	4	5	6
	All women	All women of color	African American/ Black	Asian American	Hispanic/ Latina	White
Engineering department fixed effect						
Biomedical Engineering	0.956***	−0.056***	0.019***	−0.187***	0.112***	0.918***
	(0.015)	(0.009)	(0.003)	(0.008)	(0.005)	(0.013)
Chemical Engineering	0.609***	−0.095***	0.015***	−0.258***	0.149***	0.637***
	(0.013)	(0.008)	(0.003)	(0.007)	(0.004)	(0.011)
Civil Engineering	0.519***	−0.171***	0.005**	−0.276***	0.101***	0.640***
	(0.012)	(0.007)	(0.002)	(0.006)	(0.004)	(0.010)
Mechanical Engineering	−0.100***	−0.242***	−0.008***	−0.289***	0.055***	0.103***
	(0.011)	(0.007)	(0.002)	(0.005)	(0.003)	(0.009)
General/Other Engineering	0.615***	−0.139***	−0.002	−0.296***	0.159***	0.691***
	(0.010)	(0.006)	(0.002)	(0.005)	(0.003)	(0.009)
Average department-level characteristics (in 100 units)						
Faculty Count	13.735***	3.987***	0.425***	2.865***	0.696***	8.359***
	(0.029)	(0.018)	(0.006)	(0.015)	(0.009)	(0.024)
African American/Black Women Engr Bachelor's Degree Completion	4.071***	3.772***	2.530***	1.531***	−0.289***	0.895***
	(0.271)	(0.166)	(0.056)	(0.136)	(0.083)	(0.228)
Asian American Women Engr Bachelor's Degree Completion	1.850***	0.142	−0.137***	0.324***	−0.044	1.679***
	(0.146)	(0.090)	(0.030)	(0.074)	(0.045)	(0.123)
Hispanic/Latina Women Engr Bachelor's Degree Completion	5.315***	4.871***	0.579***	1.192***	3.100***	0.890***
	(0.185)	(0.114)	(0.038)	(0.093)	(0.057)	(0.156)
Total Engr Bachelor's Degree Completion	−0.149***	−0.133***	0.011***	−0.099***	−0.044***	0.071***
	(0.009)	(0.006)	(0.002)	(0.005)	(0.003)	(0.008)
N	16,466					

Note: Models are specified as linear models. Standard errors clustered at institution by engineering department level are reported in parentheses. The sample used for these regressions includes all engineering department by year observations. Year and institutional-level fixed effects are included in the regression, but are not shown in this table. The omitted group for engineering department is Electrical/Computer Engineering and City for level of urbanicity. The coefficients associated with the percentage of women of color (WoC) residents by state are not shown.

***, **, and * denote significance levels .01, .05, and .10, respectively.

hired at least one WoC faculty between 2006 and 2016; and (Type 3) already employed a WoC engineering faculty in 2005. We exclude Type 3 departments from our sample for the logit analysis, which compares Type 2 departments to Type 1 departments.

The aggregated results for all WoC faculties are presented in Column 2 and the separate results for each racial/ethnic group in subsequent columns. We used odds ratios to present our findings. To interpret odds ratios, a coefficient larger than 1 indicates that an increase in the parameter of interest will increase the likelihood of being a Type 2 department relative to a Type 1 department, whereas a coefficient less than 1 indicates the opposite. Thus, in Column 2, relative to an engineering department in a public institution, an engineering department in a private institution is associated with only 0.67 of the relative likelihood of hiring a WoC faculty in engineering after 2005. Additionally, institutions that employ WoC in 2006 or thereafter tend to be Research I institutions, HBCUs, and in rural areas. Electrical/computer engineering departments are also more likely to employ WoC in 2006 or thereafter. Due to the reduced sample size and multicollinearity concerns, the block of departmental-level characteristics is not included in our logit regression model. Instead, the ratio of average departmental-level characteristics at Type 2 engineering departments

TABLE 4 Odds ratios from logit regression analyses of institutional- and departmental-level factors on departmental hiring of "first" women of color (WoC) engineering faculty

	Women engineering faculty					
	1 All women	2 All women of color	3 African American/ Black	4 Asian American	5 Hispanic/ Latina	6 White
Institutional-level characteristics						
Private Institution	0.908	0.672***	0.761	0.594***	0.854	0.913
	(0.193)	(0.139)	(0.204)	(0.137)	(0.188)	(0.161)
Research II Institution	0.728	0.645**	0.751	0.675**	0.626**	0.798
	(0.298)	(0.178)	(0.221)	(0.168)	(0.212)	(0.227)
All Other Institutions	0.423***	0.306***	0.385***	0.303***	0.408***	0.394***
	(0.275)	(0.170)	(0.235)	(0.164)	(0.214)	(0.210)
HBCU	1.770	2.336*	11.459***	1.341	0.488	0.404**
	(0.601)	(0.493)	(0.488)	(0.369)	(0.743)	(0.386)
Suburban	1.297	0.943	1.431	0.944	0.581**	1.419
	(0.273)	(0.176)	(0.222)	(0.173)	(0.261)	(0.219)
Town	0.615*	0.750	0.645	0.722	0.629	0.683
	(0.259)	(0.197)	(0.338)	(0.198)	(0.302)	(0.233)
Rural	1.320	2.521**	1.465	2.319**	1.772	0.829
	(0.571)	(0.441)	(0.510)	(0.373)	(0.475)	(0.439)
Engineering department fixed effect						
Biomedical Engineering	0.271***	0.346***	0.614	0.288***	0.824	0.471***
	(0.348)	(0.257)	(0.341)	(0.253)	(0.338)	(0.287)
Chemical Engineering	2.002	0.436***	0.580	0.369***	0.981	1.255
	(0.506)	(0.263)	(0.343)	(0.249)	(0.332)	(0.319)
Civil Engineering	0.429**	0.446***	0.443**	0.310***	1.298	0.758
	(0.342)	(0.232)	(0.335)	(0.228)	(0.285)	(0.272)
Mechanical Engineering	0.782	0.583**	0.697	0.501***	0.918	1.001
	(0.314)	(0.220)	(0.282)	(0.211)	(0.290)	(0.242)
General/Other Engineering	0.451*** (0.300)	0.566*** (0.214)	1.078 (0.254)	0.540*** (0.206)	1.632* (0.260)	0.904 (0.239)
Sample size						
N	574	1,028	1,400	1,126	1,392	749

Note: The values in each cell are odds ratios when comparing Type 2 departments to Type 1 departments. Standard errors for the logistic coefficients are reported in parentheses. While both Type 1 and Type 2 departments did not employ WoC faculty in 2005, Type 2 hired at least one WoC faculty between 2006 and 2016. The omitted group for engineering department is Electrical/Computer Engineering and City for level of urbanicity. The coefficients associated with the percentage of WoC residents by state are not shown.
***, **, and * denote significance levels .01, .05, and .10, respectively.

over Type 1 engineering departments is presented in Table 5. Given the suggestive evidence from Table 5, engineering departments more likely to employ WoC in 2006 or thereafter are larger departments and departments with more WoC engineering bachelor's degree completions.

Although our findings are relatively consistent with those found in Table 2, we also observed less heterogeneity across racial/ethnic groups (Columns 3 through 6). The differences in the associations with institutional and departmental factors across the three racial/ethnic groups are relatively minimal: engineering departments in HBCU institutions are more

TABLE 5 Ratio of average departmental-level characteristics at Type 2 engineering departments over Type 1 engineering departments

	Women engineering faculty					
	1 All women	2 All women of color	3 African American	4 Asian American	5 Hispanic/ Latina	6 White
Average departmental-level characteristics						
Faculty Count	2.61	1.79	1.65	1.81	1.77	1.68
African American/Black Women Engr Bachelor's Completion	2.12	1.95	3.56	1.79	1.23	0.84
Asian American Women Engr Bachelor's Completion	5.03	3.43	1.94	3.12	2.40	3.60
Hispanic/Latina Women Engr Bachelor's Completion	2.19	2.17	1.94	2.14	2.79	0.81
Total Engr Bachelor's Completion	1.65	1.89	1.75	1.87	1.73	1.64
Percentage of WoC residents within the corresponding state						
African American/Black	0.99	1.05	1.39	0.99	1.08	0.93
Asian American	1.04	1.09	0.84	1.08	1.18	1.00
Hispanic/Latina	1.19	1.14	0.88	1.14	1.41	1.02

Note: This table compares the ratio of average departmental-level characteristics at Type 2 engineering departments over Type 1 engineering departments. While both Type 1 and Type 2 departments did not employ women of color (WoC) faculty in 2005, Type 2 hired at least one WoC faculty between 2006 and 2016.

likely to hire their "first" woman African American/Black faculty, but not women Hispanic/Latina faculty. Moreover, results from Table 5 consistently suggest that engineering departments more likely to employ their first woman African American/Black, Asian American, and Hispanic/Latina engineering faculty in 2006 or thereafter are associated with higher relative counts of women engineering bachelor's degree completions from each corresponding racial/ethnic group.

7 | DISCUSSION

Given the critical importance of diversity in the engineering professoriate, a number of studies have focused on the various aspects of the experiences of WoC at the departmental, institutional, and national contexts (Turner, González, & Wood, 2008). Most studies rely on published summary statistics from NCES/National Science Foundation without further describing the institutional contexts for WoC's numerical representation. Consequently, our study advances the literature on diversity in engineering education by focusing on how institutional and departmental factors may be associated with the prevalence of underrepresentation. Consistent with organizational demography theory, we found that the number of WoC faculty within each racial/ethnic group is related to the number of WoC engineering student bachelor's degree completions from the same racial/ethnic group. This observation is also consistent with literature showing the importance of WoC faculty to the recruitment and academic success of WoC students (Ong et al., 2011; Rask & Bailey, 2002). We also identified patterns in directional differences across engineering disciplines in terms of WoC faculty representation. For example, Asian American women faculty are more likely to be in electrical/computer engineering, and Hispanic/Latina women faculty are more likely to be in chemical engineering even after controlling for other institutional and departmental factors. This finding hints at the different experiences and contexts faced by WoC faculty at the intersection of race and gender across engineering disciplines. Future studies are needed to identify the causes of these directional differences, for example, the cultural context of career choice (Fouad & Byars-Winston, 2005).

We also found that institutional-level factors are associated with the prevalence of WoC faculty. For example, African American/Black and Hispanic/Latina women faculty are more likely to be employed at institutions in rural areas, whereas Asian American women faculty are more likely to be employed at institutions in suburban areas. While we are able to establish the correlation between institutional-level factors and the prevalence of WoC faculty, our models do not uncover the mechanisms for these patterns. Based on previous literature, it is possible that engineering

PhDs may have different preferences for geographic location and level of urbanicity, and those preferences may be associated with race/ethnicity; and/or WoC engineering PhDs may systematically receive different levels of doctorate training and job preparation that facilitate different types of job attainment. From the institutional perspective, potential mechanisms could be that hiring institutions (e.g., public institutions) may have stronger external pressures and incentives to increase the diversity of their engineering faculty; and/or institutions with limited diversity in their hiring channels may only be able to assemble a smaller pool of WoC applicants. Although we present some potential mechanisms to partially explain our findings, further research needs to be conducted to uncover the mechanisms for the slow diversification of the engineering professoriate, such as that conducted by Kinoshita, Knight, Borrego, and Wall Bortz (2020) on the job offers of PhD recipients by gender and race/ethnicity.

Among engineering programs that did not employ any WoC faculty in engineering in 2005, we found that engineering departments in public institutions, Research I institutions, and larger institutions are much more likely to hire their "first" WoC faculty member. We offer compelling, albeit only suggestive, evidence that institutions with missions to serve state residents and that have wider reach due to size are more likely to diversify their engineering faculty. Our study is consistent with some evidence from the literature, which offers a critique of highly selective private institutions on the issue of diversity (Hearn & Rosinger, 2014). Additional studies are needed to better understand the recruiting and hiring practices in engineering departments, and the steps that engineering departments need take to cultivate environments for success among WoC faculty that they do hire. Future studies on the experiences of engineering WoC faculty and on engineering departmental climate and culture are needed to extend the literature and to inform systemic strategies to increase and promote diversity.

Although our focus on departmental and institutional factors highlights characteristics associated with engineering demographic faculty composition, many of these characteristics are not changeable. We are not suggesting that institutional characteristics, such as private/public or geographic location, should be or could be changed but rather that institutions with these characteristics could make more deliberate efforts in changing practices, climate, and culture or developing strategies and interventions to potentially increase their engineering faculty diversity. Policy makers and academic leaders need to commit resources both to reflection and action toward increasing and supporting the participation of WoC faculty in engineering, and toward shifting attitudes and cultures in their departments and disciplines.

Many successful workshops, classes, and programs have been implemented to improve diversity in the STEM professoriate (Jackson, Hillard, & Schneider, 2014; Rosser & Chameau, 2006). For example, the National Science Foundation's ADVANCE program provides institutional awards designed to empower participation of women in science and technology, with some initiatives focusing specifically on the career trajectories of WoC. Our study offers an important takeaway for relevant stakeholders, including funding agencies and state governments—that is, the prevalence of WoC faculty and students are linked. The level of diversity among undergraduate engineering students is correlated with the prevalence of WoC faculty. Policies targeting WoC faculty also contribute to supporting WoC students, and vice versa.

7.1 | Limitations

A limitation of our study is that the ASEE database may not be representative of all engineering faculty in the United States. Although the ASEE dataset is relatively robust and represents a large range of engineering programs, it is not exhaustive, and some engineering programs are not included in our study. Our sample is nonrandomly selected and there are faculty from small and/or unaccredited institutions who are not represented. Without further data and investigation, it is not clear whether the characteristics of smaller institutions are related to engineering faculty diversity in different ways than the institutions represented in the ASEE database. That is, we may be missing critical information regarding WoC who may be working at smaller engineering programs across the United States. The ASEE data are also self-reported by the institutions, and while there is potential that there may be some errors in reporting, ASEE checks and verifies the reported numbers. We also compared the overall summary statistics of our sample and found that the sample composition is largely consistent with the national-level summaries provided by the National Science Foundation (2017).

Furthermore, our paper does not address several important aspects regarding departmental and institutional factors, due to either data availability or the study's scope and focus. For example, our study does not take into account the role of diversity initiatives, such as those from the National Science Foundation ADVANCE program. Future research examining the influence of such programs would help further advance the literature in this field by providing a more comprehensive understanding of the factors that contribute to diversity in the professoriate. Another limitation of our study is that while we consider HBCU designations, we did not explicitly examine the role of MSIs, such as HSIs. We conducted our analyses using measures for the demographic composition of undergraduate engineering students, and found evidence that HSIs, as well as HBCUs, are more likely to employ WoC faculty in engineering. There has been growing research interest in HSIs and future research could focus on their role in contributing to diversity in engineering and workforce development.

Although our study finds that the number of WoC faculty correlates with the number of WoC engineering bachelor's degree completions, we are unable to determine the leading force of this relationship given the available data. The literature has shown evidence for both directions—the number of WoC faculty can promote WoC student enrollment (Callister, 2006; Fox, 2010) and the number of WoC student enrollment can promote WoC faculty (Kulis et al., 1999). Our study is correlational rather than causal and, thus, shows the relationships between prevalence of WoC faculty and institutional and departmental factors. With additional years of panel data, future studies can expand on this evidence to investigate further whether faculty demographic composition causally leads or follows diversity in undergraduate student populations (Kónya, 2006; Narayan & Smyth, 2009).

7.2 | Conclusion and implications

Increasing diversity in engineering faculty is important because it has the potential to (a) lead to the recruitment of talented researchers and innovators, (b) improve the quality of the research training environment; (c) broaden the perspective in setting research priorities; (d) improve the ability to perform research that acknowledges the unique experiences of individuals from diverse backgrounds; and (e) improve the nation's disparities in science and engineering by race and gender. This study provides useful insights for engineering PhD students and faculty search committees, department chairs of engineering departments, and other invested parties interested in diversifying their engineering faculty toward a more diversified engineering body.

Although the representation of women and minorities in STEM academia is improving, the change has been slow or stagnant. Our study demonstrates that institutional and departmental factors, including the prevalence of WoC undergraduate students (measured by WoC undergraduate degree completions), are associated with faculty diversity. We found that institutions that are public and are not Research I institutions are more likely to have more WoC engineering faculty. Disaggregating our analyses by race/ethnicity, institutions that award more bachelor's degrees to African American/Black women engineering undergraduate students as well as those located in a state where there are more African/Black American women residents are also more likely to employ more African American/Black women faculty in engineering. Moreover, we found this positive relationship in engineering between Asian American women undergraduate students and Asian American women faculty as well as between Hispanic/Latina undergraduate students and faculty.

Hiring more WoC faculty is not only good for innovation and engineering ingenuity but is also an effective recruitment and retention strategy for undergraduate students of color in engineering fields. With nearly 90% of engineering departments without a Latina or African American/Black woman faculty member (Figure 1), every engineering department should critically reflect on their own practices and environment to identify strategies to counteract this trend. Central to this endeavor is recognizing the value of WoC faculty as knowledge creators and innovators but also as living testaments of success for future generations of WoC engineering scholars. It is clear that supporting WoC faculty also supports WoC undergraduates. For this reason, it is imperative for administrators and faculty to recruit WoC in environments where women students may seek mentors with whom they identify. Investing time in learning about disparities in engineering and reflecting on how these systemic challenges can be overcome is critical to collective action, change, and transformation.

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ENDNOTE

[1] With a two-step generalized least squares (GLS) procedure, one can estimate a fixed effect model first and then estimate the coefficients of the time invariant covariates subsequently. We do not adopt this procedure because Oaxaca and Geisler (2003) have shown that the pooled OLS estimators of the coefficients on time invariant covariates are equivalent to those from the two-step GLS estimator.

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