

Family formation and the career trajectories of women engineering PhDs

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Abstract

Purpose – The underrepresentation of women in engineering has important consequences for meeting the need for a larger, talented scientific and technological labor force. Increasing the proportion of women faculty in engineering will help increase the persistence probabilities of women undergraduate and graduate students in engineering, as well as contribute to the range and diversity of ideas toward innovations and solutions to the greatest engineering challenges. This study aims to examine the association among gender, family formation and post-PhD employment patterns of a cohort of engineering doctorates.

Design/methodology/approach – Using the National Science Foundation’s Survey of Doctorate Recipients data, 2001–2010, descriptive and multinomial logit regression analyses are conducted to illustrate the career trajectories of engineering PhDs over a ten-year period.

Findings – The career trajectories of engineering PhDs are nonlinear, and transitions between employment sectors commonly occur over the ten-year time period studied. Although women engineering PhDs with young dependents are less likely to be employed initially after PhD completion, they tend to enter the workforce in the academic sector as time progresses. Early post-PhD employment as a postdoctoral researcher or in the academic sector contributes to the pursuit of the professoriate downstream.

Originality/value – While previous studies tend to focus on the early career outcomes of science and engineering students, this study contributes to the literature by focusing on the long-term career outcomes of engineering doctorates. Research findings provide engineering PhD students and PhDs with more information regarding potential post-PhD career trajectories, highlighting the multitude of career options and transitions that occur over time. Research findings also provide higher education administrators and doctoral program stakeholders with foundational information toward designing and revitalizing professional development programs to help PhD students prepare for the workforce. The findings have the potential to be applied toward helping increase diversity by shaping policies and programs to encourage multiple alternative career pathways to the professoriate.

Keywords PhDs, Women, Careers, Faculty, Engineering, Family formation

Paper type Research paper



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Introduction

Women engineering doctorates' post-PhD employment patterns remain markedly different compared to those of their male counterparts [National Science Foundation, National Center for Science and Engineering Statistics (NSF NCSES), 2017b, 2020]. Previous studies have attributed differences in postgraduation employment outcomes between men and women in part to challenges associated with work–life integration (Mason and Goulden, 2002; National Research Council [NRC], 2010; Wolfinger *et al.*, 2009; Xie and Shauman, 2003). Workplaces, including academic institutions, continue to be organized around “ideal worker” norms, which expect workers to singularly prioritize work (Acker, 1990; Ward and Wolf-Wendel, 2012, 2016). “Ideal worker” norms place strain on many workers, who have other nonwork responsibilities, such as caring for young dependents or aging parents. These norms particularly disadvantage women because women are often viewed as caretakers, and their commitment to and successes in professional pursuits tend to be questioned (Lester, 2015; Ward and Wolf-Wendel, 2012, 2016). Parenthood, in particular, has been shown to disadvantage women in the workplace, including academia (Cech and Blair-Loy, 2019; Mason and Goulden, 2002; Mason *et al.*, 2013; Mirick and Wladkowski, 2018; Wolf-Wendel and Ward, 2014). Thus, this study examines the intersection between family formation and post-PhD employment patterns among a cohort of engineering PhDs between 2001 and 2010.

Gender disparities in science, technology, engineering and mathematics (STEM) fields has been a persistent issue. The underrepresentation of women is particularly pronounced in engineering fields, where women comprise only 16.4% of the tenure track faculty (NSF NCSES, 2017b). At the highest level of the professoriate, women comprise only 12% of full professors in engineering (NSF NCSES, 2017b). In addition to challenges associated with ideal worker norms, the lower representation of women in tenure track faculty positions has been attributed partially to limited transparency regarding career opportunities, the lower proportions of women applying for tenure track faculty positions and the relative lack of role models (Ceci and Williams, 2011; Williams and Ceci, 2015). Beyond the professoriate, the departure of women from engineering occupations has been attributed to experiences in the workplace, such as the lack of support in advancement opportunities and in balancing work and family roles (Fouad *et al.*, 2016, 2020; Kossek *et al.*, 2021). The importance of parenthood in the career trajectories of scientists and engineers is well documented – while many STEM workers, both men and women, leave employment following the birth or adoption of their children, women do so at higher rates than men (Cech and Blair-Loy, 2019; Goulden *et al.*, 2011).

This study focuses on women engineering PhDs and their career paths from graduation to at least ten years following PhD completion. Using data from the National Science Foundation's Survey of Doctorate Recipients (NSF SDR 2001–2010), descriptive and multinomial logit regression analyses illustrate how demographic factors and family formation are associated with the long-term career paths of 819 engineering PhDs. The life course perspective, which focuses on the domains of education, family and work in the multitude of career trajectories (Elder, 1994, 1998; Elder and Giele, 2009; Moen, 2016; Xie and Shauman, 2003), informs the empirical approach addressing the following research questions:

- RQ1. What are the employment trends of engineering PhDs over time as a function of gender and family formation?
- RQ2. How does family formation during the PhD and early post-PhD employment associate with attainment of a tenure track faculty position ten years after PhD completion? How does family formation and early post-PhD employment associate with attainment of industry, government and nontenure track academic positions?

The research findings regarding the long-term career paths of engineering PhDs have the potential to contribute to:

- encourage PhD students and PhDs to envision the multitude of career possibilities and trajectories, and the potential transitions that may occur over the career span; and
- aid PhD program administrators and other stakeholders to enhance and revitalize professional development training to reflect the career opportunities available to their graduates.

Findings also have implications for encouraging more women engineering doctorates to pursue careers in the professoriate, as well as to help shape institutional policies to accommodate family formation and alternative career pathways to the professoriate.

Literature review

Long-term employment outcomes of PhDs

The doctorate is a significant undertaking for students and their families, PhD advisors, doctoral programs and academic institutions. These personal and organizational investments are made in terms of time, effort, emotions, money and other resources (Ehrenberg *et al.*, 2010; Lovitts, 2001). The USA also contributes to the advanced training of doctoral students through fellowships and other support. Despite these significant investments, relatively little is known regarding the longitudinal career patterns of doctorates, particularly in engineering [Council of Graduate Schools (CGS), 2014; Council of Graduate Schools and Educational Testing Service, 2012]. Indeed, the Council of Graduate Schools and Educational Testing Service (2012, p. 1) stated that:

The United States is generally recognized as having the most vigorous and dynamic system of graduate education in the world, but little is known at the granular level about what our graduates do, how their work life progresses, and how well the preparation they receive equips them for the careers they pursue.

Identifying the long-term career outcomes of PhDs has important implications for understanding the returns associated with completing the doctorate. Providing greater career transparency – knowledge of career options and employment outlooks – can help motivate PhD students to progress and complete their degrees (Council of Graduate Schools and Educational Testing Service, 2012). With the ten-year completion rate for engineering doctoral students at only 63% (65% for men and 56% for women), it is imperative to uncover new opportunities for increasing interest and persistence in the engineering PhD (CGS, 2014). Improving career transparency and promoting knowledge regarding the multitude of career opportunities and transitions that may occur over a career span can potentially help increase interest, persistence and diversity in the engineering doctorate.

Many studies on the career outcomes of doctorates have tended to focus on PhDs' career intentions and early career attainment (Choe and Borrego, 2020; Gibbs and Griffin, 2013; Gibbs *et al.*, 2014; Kim *et al.*, 2020; Main, 2012; Nerad *et al.*, 2007; NRC, 2010). With increased availability of long-term employment data, the number of studies highlighting PhDs' long-term career trajectories has expanded (Denton *et al.*, 2019; Kahn and Ginther, 2017; Kulp, 2020; Main, 2016; Main and Wang, 2019; Main *et al.*, 2019, 2021; Nerad and Cerny, 1999a, 1999b, 2003; Wang and Main, 2021; Webber and González Canché, 2018; Yang and Webber, 2015). Early studies on the long-term employment outcomes of PhDs were conducted by Nerad and Cerny (Nerad and Cerny, 1999a, 1999b, 2003) using their PhDs Ten Years Later

study, which includes data from PhDs in biochemistry, computer science, electrical engineering, English, mathematics and political science.

Since the PhDs Ten Years Later study, a number of studies have used the NSF SDR to investigate the long-term career outcomes of PhDs. For example, [Yang and Webber \(2015\)](#) used the NSF SDR to examine the role of postdoctoral positions in the career paths of the 1997/1998 cohort of PhDs in science, engineering and health. They found that postdoctoral positions contribute to attainment of academic positions, including tenure track faculty positions ([Yang and Webber, 2015](#)). Meanwhile, [Kahn and Ginther \(2017\)](#) examined the impact of postdoctoral positions on the long-term career outcomes of PhDs in biomedicine and found that postdoctoral research positions are critical to obtaining tenure track faculty positions. [Wang and Main \(2021\)](#) similarly found the importance of postdoctoral research positions in the path to the professoriate. In the same vein, [Main et al. \(2021\)](#) focused on engineering PhDs and found similar trends – compared to PhDs who started in government or industry positions after PhD completion, those who held postdoc positions were more likely to obtain tenure track faculty positions.

Early career outcomes of engineering PhDs

Examining the employment outcomes of engineering PhDs is a growing research area. Previous studies on career paths have tended to aggregate science and engineering together, often due to issues associated with sample sizes. However, the engineering field has characteristics that warrant separate investigation from the sciences:

- patterns in the early career outcomes of doctorates vary between science and engineering; and
- the ways in which career paths are gendered may be different between science and engineering ([Fox and Stephan, 2001](#)) due to the marked difference in the overall gender composition of doctorates in engineering compared to those in science and other fields.

In terms of early career outcomes following PhD completion, industry or business is a prevalent employment destination for engineers. In 2019, 74% of engineering PhDs worked in the industry sector compared to only 42% of life sciences PhDs ([NSF NCSES, 2020](#)). Meanwhile, 37% of life sciences PhDs worked in academe compared to only 12% of engineering PhDs ([NSF NCSES, 2020](#)). Smaller proportions of engineering PhDs worked in government (8%) and in nonprofit organizations (3%) ([NSF NCSES, 2020](#)). These trends in engineering PhD employment have largely been consistent over time. In the context of examining career paths to the professoriate, these trends suggest differences in student career interest, career opportunities and job placement between science and engineering PhDs.

In terms of career-related interests, [Choe and Borrego \(2020\)](#) used cluster analysis to examine the career trajectories of 249 engineering thesis master's and doctoral students. They found that students with internships during their graduate education are more likely to pursue industry careers. [Roach and Sauermann \(2010\)](#) conducted a survey of 400 science and engineering PhD students and found that PhD students have different expectations between careers in academia and industry. Whereas PhD students perceive academia to offer greater freedom associated with choosing research projects and collaborating with others at different organizations, PhD students perceive industry to offer higher salaries and more resources ([Roach and Sauermann, 2010](#)). Moreover, they showed that PhD students who prioritize salary, access to resources and downstream research and development are more likely to be interested in industry careers. PhD students who have a stronger

preference for conducting basic research and choosing research projects, and who have the ability to publish, are more likely to be interested in academic careers (Roach and Sauermann, 2010).

Although PhD students have interests in multiple career sectors (Choe and Borrego, 2020), previous research has shown that the majority of PhD students aspire to academic careers (Ehrenberg *et al.*, 2010; Gibbs *et al.*, 2014; Main, 2012; Roach and Sauermann, 2017). Roach and Sauermann (2017) showed that although 80% of science and engineering PhD students were interested in faculty careers at the beginning of their doctoral program, after three years, only 55% of the sample remained interested in faculty careers. Nevertheless, 55% still constitutes a large share, and is consistent with Main's (2012) finding that 60% of engineering students at a research-intensive institution were interested in pursuing tenure track faculty positions. While the majority of both science and engineering PhD students intend to pursue academic careers, attainment of tenure track faculty positions varies by broad field and gender.

Gendered career paths

The gender imbalance in engineering degree attainment and participation in the labor force is perhaps one of the most critically persistent issues that has garnered the attention of students, researchers, K-12 and higher education professionals and industry and government stakeholders (Buse *et al.*, 2013; Fouad, 2011, 2016, 2020; Hewlett and Hidden Brain, 2008; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; National Academy of Engineering, 2018; NSF NCSES, 2019). Turning to those with PhDs, patterns in PhD degree enrollment and persistence in engineering vary by gender. The share of PhDs awarded to women in engineering continue to be lower than the share of PhDs awarded to women in many other fields. In 2019, 24% of engineering degrees were awarded to women, compared to 55% in life sciences, 34% in physical sciences, 26% in mathematics, 60% in psychology and social sciences, 51% in humanities and arts and 69% in education (NSF NCSES, 2020). Compared to many other fields, women also pursue PhDs in engineering at lower rates than men. Based on data from 589 colleges and universities participating in the 2018 CGS/GRE Survey of Graduate Enrollment and Degrees, women comprised 28% of enrolled engineering PhD students in Fall 2018 (Okahana and Zhou, 2019). In addition to women's lower enrollment in engineering PhD programs, there are also gender differences in the ten-year PhD completion rates. The Council of Graduate Schools (2008) report that the ten-year completion rate for women in engineering is 56%, whereas the completion rate for men in engineering is higher at 65%. Moreover, women are more likely than men to have a longer time to degree, with 25% graduating between seven and ten years of PhD study compared to only 18% of men (CGS, 2008).

In 2017, 19% of engineering PhDs working in four-year educational institutions were women, compared to 38% of science PhDs (NSF NCSES, 2017b). Focusing on the professoriate in four-year educational institutions, gender differences between science and engineering fields become more apparent. In 2017, only 12% of full professors in engineering were women, compared to 27% in science (NSF NCSES, 2017b). At the junior faculty level, 21% of assistant professors in engineering were women, compared to 43% in science fields (NSF NCSES, 2017b). There are, of course, variations by department and by year in terms of the proportion of female faculty, as well as exceptions, but this overall trend suggests that a focused examination of the career trajectories of engineering PhDs extends the literature and provides foundational knowledge toward designing interventions to prepare doctorates for the opportunities available to graduates in their field. This is especially important in the context of previous findings that highlight the mismatch

between PhD student career interest, professional development training offered by doctoral education programs and post-PhD employment outcomes (Austin and Wulff, 2004; Cyranoski *et al.*, 2011; Golde and Dore, 2001).

Webber and González Canché (2018) suggest that for science and engineering PhDs, gender gaps in academic career outcomes in terms of attainment of tenure track faculty positions appear to be closing over time. However, previous studies have shown that the underrepresentation of women in the professoriate stems partially from the relative lack of career transparency, from relatively fewer women applying for tenure track faculty positions and from the lack of role models (Ceci and Williams, 2011; Williams and Ceci, 2015). The participation of women in tenure track faculty positions in engineering is thus limited because they comprise a much smaller share of the applicant pool from which to draw faculty candidates. In terms of shifting the gender inequality in the professoriate, the representation of women faculty is a critical determinant of the probability of persistence and the quality of experiences among female graduate students (Main, 2014, 2018). Female role models and mentors are positively associated with female students' higher academic persistence (Bettinger and Long, 2005; Carrell *et al.*, 2010; Main, 2014, 2018; Rask and Bailey, 2002). Higher proportions of women engineering faculty, instructors and role models have important implications for increasing the number and diversity of current and future engineering graduates (Main *et al.*, 2020). The interconnectedness between the levels of diversity in the composition of engineering undergraduates, PhDs and professors, as well as the engineering workforce, requires a focused effort on identifying the pathways and critical life stage transitions of engineers. Increasing the participation of women in the engineering professoriate has important implications for improving the experiences and persistence rates of female engineering graduate and undergraduate students, and also meeting the nation's demand for a larger and more representative scientific and technological labor force (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007).

Family formation

While it is well-known that women leave engineering occupations at higher rates than men, how career trajectories in engineering are shaped by family formation (parenthood) among PhDs warrants further study. Understanding the career trajectories of women engineering PhDs is especially important toward addressing social justice concerns, and also because of the significant investments that have been made in their education and training. The loss of women in the talent pool at this advanced stage is a social justice issue, and also limits innovation and economic advances (National Academy of Engineering, 2018).

Previous studies have found that parenthood (having young dependents in the household) has profound effects on the career trajectories of women (Ehrenberg *et al.*, 2010; Goulden *et al.*, 2011; Main *et al.*, 2019; Main and Schimpf, 2017; Mason and Goulden, 2002; Perna, 2005; Williams, 2000; Xie and Shauman, 2003). Women PhDs with young children experience unique barriers to career formation when they assume primary responsibility for childcare and household labor (Xie and Shauman, 2003). Cech and Blair-Loy (2019) showed that parenthood has important implications for who remains in the STEM workforce. They found that across STEM fields, and regardless of discipline, race and other demographic factors, new mothers are relatively more likely than new fathers to leave the STEM workforce, to switch from full-time to part-time work or to exit the labor force. They indicate that it is the combination of full-time work in STEM fields and childcare that parents find difficult to manage because many of the parents in their sample leave STEM fields to work full-time in other fields. And in general, new parents are more likely than those without

dependents to leave the STEM labor force, and while some eventually return to work in STEM fields, many may not necessarily return to STEM occupations over time (Cech and Blair-Loy, 2019).

Fouad *et al.* (2011, 2016) also showed the importance of work–life balance for women in engineering occupations. Among women with undergraduate degrees in engineering, the differences between those who stayed and those who left engineering occupations were due not to differences in self-confidence or changes in interests, but rather to differences in work-related support for work–life roles and in receiving support for advancement (Fouad *et al.*, 2016). Comparing men and women engineers, Fouad *et al.* (2020) showed that the top four reasons that men left engineering positions include lack of advancement opportunities, loss of interest, salary and dissatisfaction with daily tasks. While women also reported lack of advancement opportunities, loss of interest and dissatisfaction with daily tasks as reasons for leaving engineering positions, the highest reported reason was the lack of time available to spend with their families. That is, in the context of the Theory of Work Adjustment framework, Fouad *et al.* (2020) found that women who left engineering positions felt that their status and comfort needs were not being met. While comfort values include elements of the work environment related to security, compensation, working conditions and level of engaging and varied work, status values reflect the availability of advancement opportunities, recognition, authority and status.

Compared to men with children, women with children are 35% less likely to enter a tenure track faculty position in the sciences (Goulden *et al.*, 2011). And among those who enter a tenure track faculty position, women with children are 27% less likely than men with children to achieve tenure (Mason *et al.*, 2013). However, research by Kulp (2020) found that PhD mothers are just as likely to obtain tenure track faculty positions as PhD fathers based on data from the NSF SDR. The primary difference that Kulp (2020) identified in employment outcomes between PhD mothers and their counterparts is that PhD mothers are more likely to work at nonresearch institutions. Meanwhile, Main *et al.* (2019) showed that there are multiple pathways to the professoriate among PhDs in humanities and humanistic social sciences when viewed across the career span. Although the career patterns of men and women vary by marital status and presence of young dependents, when examined longitudinally, women with young children at PhD completion are just as likely as women who did not have children at PhD completion to hold a tenure track faculty position eight years after PhD completion (Main *et al.*, 2019).

Women who assume a larger share of childcare responsibilities may also face additional challenges in the progression of their careers (Xie and Shauman, 2003). They may feel the pressures of the “ideal worker” norms more acutely (Acker, 1990; Hochschild, 1995; Sallee, 2014; Williams, 2000). Previous research further suggests that “ideal worker” pressures may be stronger for women because women have traditionally been expected to assume childcare and other family needs (Acker, 1990; Hochschild, 1995; Sallee, 2014; Williams, 2000). However, the pressures associated with “ideal worker” norms are not limited to mothers, and are increasingly becoming more visible among fathers (Cech and Blair-Loy, 2014; Sallee, 2014). With the rise of dual career couples, these challenges have become more pronounced despite workplace efforts to provide work–life policies across employment sectors, including in academic settings (Lester, 2015; Ward and Wolf-Wendel, 2012, 2016). For some faculty in STEM fields, ideal worker norms are coupled with the fear of negative consequences associated with usage of family-related benefits policies (Cech and Blair-Loy, 2014).

For many PhD students, family formation contributes to shaping career decisions. The development of professional trajectories is complex, and for women in engineering, career choices may be constrained in the context of caring for young dependents while navigating

pathways to the professoriate where there are fewer women who can serve as role models, mentors and advocates (Cech and Blair-Loy, 2014; Ceci and Williams, 2011; Goulden *et al.*, 2011; Mason *et al.*, 2013; Williams and Ceci, 2015). This study extends the literature on long-term employment outcomes of PhDs and occupational change, with particular attention to the field of engineering. This study focuses on family formation in the career progression and paths to the professoriate between men and women over time from PhD completion through ten years of post-PhD employment. In addition to investigating career paths to the professoriate, this study also illustrates the multitude of career paths into the other employment sectors: industry, government and nontenure track academic. Research findings contribute to the ongoing dialogue on clarifying post-PhD career opportunities and professional development training to prepare PhDs for the multitude of career paths, as well as to supporting a diverse engineering workforce.

Conceptual framework

The life course perspective provides a framework to examine intersecting domains, such as gender and family formation, in the longitudinal career trajectories of doctorates (Elder, 1994, 1998; Elder and Giele, 2009; Shanahan *et al.*, 2016a, 2016b; Xie and Shauman, 2003). Gender and family formation have been shown to influence graduate education experiences and career trajectories in science and engineering fields (Moen, 2016; Ward and Wolf-Wendel, 2012, 2016; Wolfinger *et al.*, 2008, 2009). Because the life course perspective highlights the “multiple trajectories in the domains of education, family, and work,” (Xie and Shauman, 2003, p. 14), this study focuses on the career trajectories of engineering PhDs across employment sectors through a ten-year time span.

The life course perspective highlights the elements of timing, transitions and trajectories of work (Elder and George, 2016; Moen, 2016). In terms of timing, the age of the PhD at degree completion, the PhD completion cohort year and the timing of family formation for some PhDs are considered in this study. In terms of transitions and trajectories in the career pathway, the association between early post-PhD employment (in 2001) and the PhD’s employment sector ten years after PhD completion, as well as the transitions among the various employment sectors over time, are examined. Individual lives are linked to family and other shared relationships, such that this interdependence is operationalized through the individual’s marital status and family formation status – young dependents under six in the household. Moen (2016) highlights the differences in men’s and women’s work lives as a result of constrained agency, socialization, historical and environmental context, accumulated advantages and disadvantages and ideal worker norms. Moen also indicates that “policies, traditions, and biases serve to foster and reproduce disparities by social class, race, nativity, gender, and age” (p. 250). Accordingly, this study also takes into account gender, race/ethnicity and US citizenship. While individual choice can be constrained by context and institutional factors, even unintentionally, there is a degree of human agency and personal control over the direction of career patterns. Career interest during graduate education is not directly measured, but previous research has shown that the majority of PhD students initially intend to pursue academic careers as tenure track faculty members (Ehrenberg *et al.*, 2010; Main, 2012; Roach and Sauermann, 2017). Thus, informed by the life course perspective, this study highlights the career paths to the professoriate and the other multitude of career paths of engineering PhDs.

Data

The data come from the NSF SDR 2001–2010. The SDR includes employment data on individuals who earned a doctoral degree in a science, engineering or health field from a US

institution. The SDR has been administered every two to three years since 1973, and thus provides rich information regarding employment histories of doctorates, as well as demographic information including educational history, marital status and number of children. For this study, the sample is limited to PhDs who earned a degree in engineering between 1996 and 2000 from a US institution, with the 2001 year as the focal point for analysis. Due to NSF's sampling strategy, respondents to the 2001 SDR wave lived in the USA during the survey reference week and were not 76 or older.

Figure 1 illustrates the early employment outcomes of engineering PhDs in select years between 1996 and 2019 (NSF NCSES, 2017a, 2020). While there have been some changes, Figure 1 shows that the majority of engineering PhDs work in industry. Employment in the academic sector is consistently the second most prevalent destination for engineering PhDs.

To model the employment patterns of engineering doctorates over a ten-year period, the sample is limited to engineering PhDs who responded to all of the five following survey waves: 2001, 2003, 2006, 2008 and 2010. The resulting data set includes 819 engineering PhDs with an average age of 35 years. Table 1 summarizes the characteristics of the sample. Of the sample, 17% are women, 83% are men and 58% identified as US citizens. For race/ethnicity, 55% of the respondents indicated White, 33.3% reported Asian, 5.4% indicated African American/Black and 5.6% reported Hispanic/Latinx. At the time of PhD completion, 75% of respondents were married and 37% reported having at least one dependent under six years of age living in the household. Consistent with Figure 1, the majority of respondents (67%) worked in industry.

Methods

RQ1: What are the employment patterns of engineering doctorates over time as a function of gender and family status?

To model the employment patterns of engineering doctorates over a ten-year period, the proportions of engineering PhDs who reported working in each of the following employment sectors were calculated: industry or business, academia or government in 2001, 2003, 2006, 2008

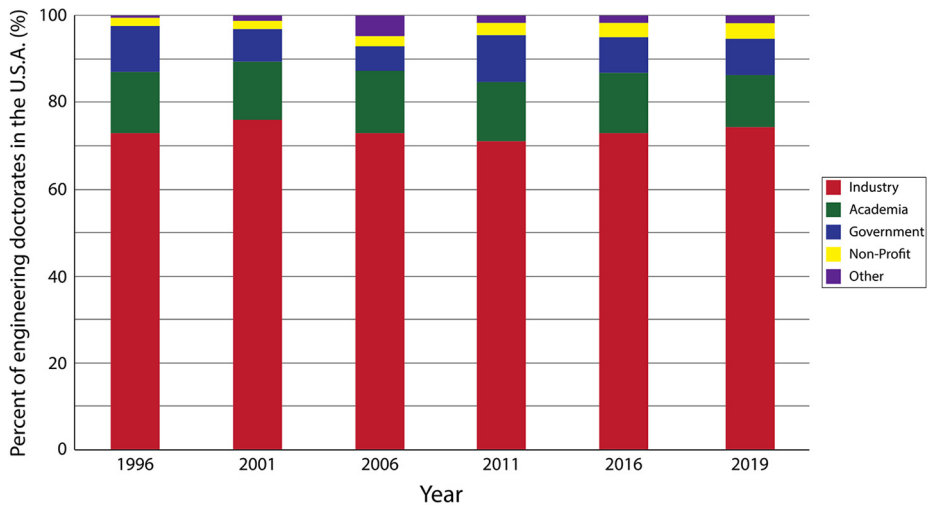


Figure 1.
Proportion of engineering PhDs with positions across different employment sectors

Source: National Science Foundation Survey of Earned Doctorates, 2017 and 2020

Table 1.

Summary statistics

Variables	(%)
<i>Gender</i>	
Women	16.7
Men	83.3
<i>Race/ethnicity</i>	
African American/Black	5.4
Asian	33.3
Hispanic/Latinx	5.6
White	55.0
Other	0.7
<i>PhD characteristics</i>	
US Citizen	58.3
Married	74.4
Has dependent(s) under age 6	36.2
<i>Employment sector</i>	
Academic	25.3
Industry	66.5
Government	6.5
Unemployed/not in labor force	1.7
<i>N</i>	819

and 2010. Additionally, the proportions of engineering PhDs who reported being unemployed or not in the labor force across these survey waves were also calculated. While the respondents provided important information regarding their employment trajectories, this sample may not necessarily be representative of all engineering PhDs. As the intersection of gender and family status is the primary focus of this paper, Figure 2 compares the career trajectories of men and women engineering PhDs with and without young dependents (under the age of six) in the household at the time of PhD completion. Figure 2 illustrates the career paths of engineering PhDs by gender, family status and employment sector over time.

RQ2: How does family formation during the PhD and early post-PhD employment associate with attainment of a tenure track faculty position ten years after PhD completion? How does family formation and early post-PhD employment associate with attainment of industry, government and nontenure track academic positions?

Multinomial logit regression is applied to examine how family formation and early post-PhD employment sector correlate with the PhD's employment position/sector ten years after PhD completion. There are multiple possible discrete outcomes for employment position/sector in 2010: tenure track faculty position, industry sector, government sector or other academic position. Other academic positions include all nontenure track positions in the academic sector, such as adjunct faculty or administration. The base category in the multinomial logit regression is employment in the industry sector. The year 2010 represents at least ten years since PhD completion for the survey respondents.

Explanatory variables include gender, family status (defined as having at least one child under six years old living in the household) and interaction between gender and family status. The model incorporates employment position in 2001, which comprises the following positions: tenure track faculty, postdoctoral research scholar and other academic (nontenure track) positions, as well as the following employment sectors: industry and government. Unemployment/not in the labor force in 2001 is also considered. The model also includes race/ethnicity, US citizenship, indicator for

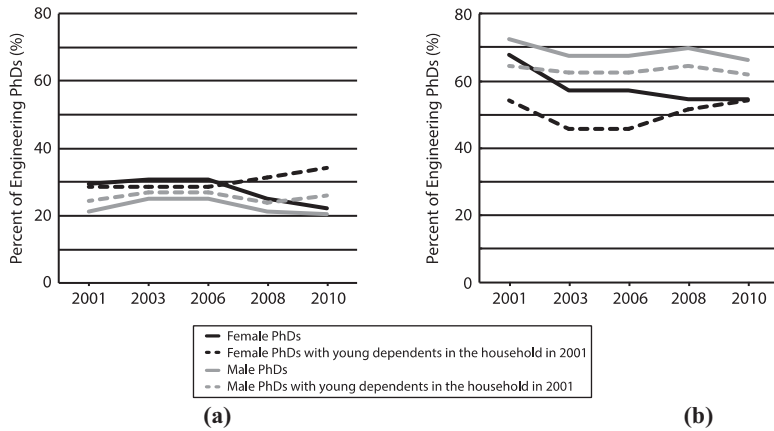
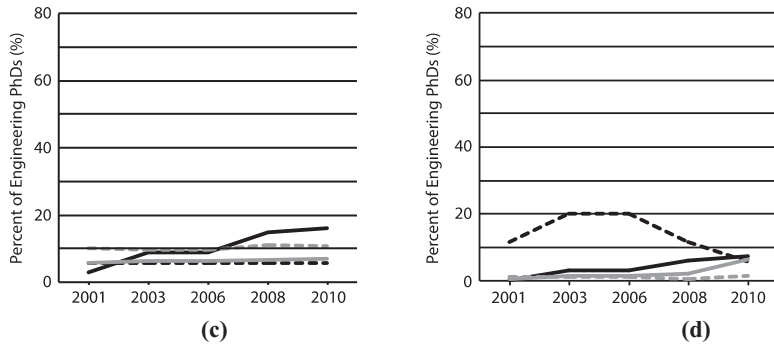


Figure 2. Percentage of engineering PhDs holding positions across different employment sectors between 2001 and 2010



Notes: (a) Academic; (b) industry; (c) government; (d) unemployed

respondent with disability, age at PhD completion, age squared, year of PhD completion and marital status. Race/ethnicity includes White, Asian and Underrepresented Racially Minoritized (URM) PhDs, which include African American, Hispanic/Latinx and Native American/Pacific Islander PhDs. The results from the multinomial logit regression analysis are summarized in [Table 2](#).

Results

The career trajectories of engineering doctorates by gender and family formation

[Figure 2](#) illustrates changes in employment sector patterns across four groups:

- (1) female engineering PhDs with children under six in the household during PhD completion;
- (2) female engineering PhDs;
- (3) male engineering doctorates with children under six in the household during PhD completion; and
- (4) male engineering PhDs.

Table 2.
Multinomial logit
regression marginal
effects on
employment outcome
in 2010

Variables	Tenure track		Other academic		Government	
	Margin	Std. Err.	Margin	Std. Err.	Margin	Std. Err.
Women	-0.042	0.035	0.053*	0.023	0.052*	0.021
Asian	0.022	0.046	0.007	0.056	-0.010	0.035
URM	0.009	0.031	0.017	0.045	0.028	0.027
US citizen	-0.006	0.022	0.040+	0.021	-0.012	0.018
Age	0.012	0.018	0.005	0.012	0.011	0.015
<i>Responses in 2001</i>						
Married	0.012	0.027	0.027	0.024	-0.029	0.020
Dependents < 6	0.017	0.025	0.022	0.024	0.017	0.022
Women*Dependents	0.014	0.052	-0.018	0.041	-0.122*	0.054
<i>Employment in 2001</i>						
Government	0.081+	0.049	0.019	0.043	0.222*	0.024
Tenure track faculty	0.435*	0.048	0.176*	0.040	-0.827*	0.117
Postdoc	0.224*	0.032	0.130*	0.033	0.102*	0.034
Other academic	0.117*	0.025	0.131*	0.020	0.043+	0.023
Unemployed	0.066	0.071	0.035	0.047	0.101*	0.041

Notes: PhD completion year, age squared and indicator for PhD with disability were included in the model, but are not shown. Comparison groups are industry for employment in 2001 and White for race/ethnicity. * $p < 0.05$, + $p < 0.10$, $N = 819$ observations

Each graph shows the participation of each of the four groups across time: 2001, 2003, 2006, 2008 and 2010. Panel A shows the proportion of PhDs who were in the academic sector between 2001 and 2010, whereas Panel B illustrates the proportion of PhDs in industry/business, Panel C the proportion of PhDs in government and Panel D the proportion of PhDs unemployed/not in the labor force.

Panel A shows the participation trends in the academic sector, which includes tenure track faculty, adjunct faculty, administrator and other positions. During the 2001–2010 time period, between 20% and 40% of engineering PhDs worked in the academic sector. Starting around 2006, there is a decline in the proportion of women PhDs who reported not having young dependents at the time of their PhD completion. In contrast, there is an increase in the proportion of women PhDs who reported having young dependents at PhD completion.

Compared to female engineering PhDs, higher proportions of male engineering PhDs work in the industry/business sector (Panel B). However, disaggregating the employment patterns in industry/business by gender and family status shows that the pattern differs between engineering PhDs with and without dependents in the household at the time of PhD completion. Although a lower proportion of female engineering PhDs with young dependents reported working in industry/business in 2001, by 2010, their proportion matches that of female engineering PhDs who did not have young dependents in the household at the time of PhD completion.

Panel C focuses on engineering PhDs who worked in the government sector. Compared to the academic and industry sectors, a smaller proportion of engineering PhDs worked in government. In general, the patterns across the subgroups are constant across time, except that the proportion of women engineering PhDs working in government increases slightly over the time period.

Panel D shows the proportions of engineering PhDs unemployed/not in the labor force by subgroup. Whereas nearly every subgroup of engineering PhDs has a very low

unemployment rate in 2001, about 10% of female engineering PhDs with young dependents report being out of the workforce immediately following PhD completion. The proportion of female engineering PhDs with young dependents reporting that they are unemployed increases in 2003, plateaus through 2006 and then decreases thereafter. Female engineering PhDs with young dependents appear to join the workforce after 2006, which coincides with increases in their participation in the academic and industry sectors. Men's unemployment patterns, however, do not appear to differ based on family formation.

Family formation during PhD and career trajectories

The multinomial logit regression results are presented in [Table 2](#). As described in the methods section, the outcome variable is employment position/sector in 2010 with the base category being employment in the industry sector.

Tenure track faculty: When examining employment outcomes over a longer time span, rather than the first/early post-PhD employment, the likelihood of holding a tenure track faculty position does not appear to differ between men and women or between those with and without young dependents at the time of PhD completion. However, employment positions in 2001 are associated with later career outcomes. For example, engineering PhDs who are already working in tenure track faculty positions in 2001 remain in the professoriate in 2010. Compared to engineering PhDs who begin their post-PhD careers in industry, those who begin as a postdoctoral research scholar or in another academic position are 22.4 and 11.7 percentage points more likely to hold a tenure track faculty position in 2010, respectively.

Other academic: Women are more likely than men to work in the nontenure track academic sector. Conversely, men are more likely to work in industry. Engineering PhDs who are employed in academic-related work in 2001, such as tenure track faculty, postdoctoral research scholar or other academic positions, are also more likely to work in the nontenure track academic sector than in industry.

Government sector: Women are 5.2 percentage points more likely than men to work in the government sector, rather than the industry sector. Women engineering PhDs with young dependents are less likely to work in the government sector compared to their counterparts. Engineering PhDs who started out in tenure track faculty positions are less likely than those who started out in industry positions to transition into the government sector. Engineering PhDs who reported initially being out of the workforce in 2001 are 10.1 percentage points more likely to work in the government sector than industry ten years after PhD completion.

Discussion

The life course perspective provides a framework to examine the long-term career trajectories of engineering PhDs at the intersection of gender, family formation and early career outcomes. The descriptive and multinomial logit regression analyses considered how these factors are associated with attainment of tenure track faculty positions, as well as employment in industry, other academic and government sectors, ten years after PhD completion. Consistent with the life course perspective, which highlights the importance of timing, transitions and trajectories of work, the research findings show that engineering PhDs have a multitude of career destinations and transitions across employment sectors.

[Figure 2](#) highlights the permeability between the different employment sectors, and the employment transitions that many engineering PhDs make over their career span, providing current and prospective engineering PhDs with greater insights regarding their long-term career opportunities. Importantly, it shows that career paths are nonlinear and

highlights the need to prepare PhDs for a multitude of careers and professional skills that are relevant across employment sectors.

Similar to previous studies (Kulp, 2020), women are more likely to work in the nontenure track academic sector, rather than in industry. And consistent with previous findings (NSF NCSES, 2017b), men with engineering doctorates are more likely than women to hold positions in industry. In engineering specifically, women PhDs are more likely to work in the academic sector. Altogether, the findings suggest that there are multiple opportunities after PhD completion to potentially recruit women engineering PhDs into tenure track faculty and other academic positions toward helping reduce the underrepresentation of women in engineering fields.

In terms of paths to the professoriate, an important takeaway is that the early post-PhD employment position/sector, specifically postdoctoral research or academic positions (in contrast to work in industry), is associated with attainment of a tenure track faculty position further down the career path. Main *et al.* (2021), in particular, also shows that engineering PhDs who have initial appointments as postdoctoral research positions are more likely than engineering PhDs who have other nontenure track academic positions to subsequently obtain a tenure track faculty position. For PhDs deciding among job offers, these findings may help guide their initial choice depending on their career interests and goals. It is also important to highlight the permeability between sectors, such that even if PhDs were to start their careers in industry or government sectors, but have aspirations for tenure track faculty positions, transition into the professoriate is possible over the career span.

Leveraging the life course perspective as a framework highlights the development of career trajectories over time. Similar to research findings from Cech and Blair-Loy (2019) and Goulden *et al.* (2011), parenthood affects men and women differently in terms of participation in the labor force post-PhD completion. Men's employment patterns do not appear to differ between those with young dependents at the time of PhD completion and those who reported not having young dependents at the time of PhD completion. Nearly 20% of women engineering PhDs with young dependents are initially out of the workforce during the time period after PhD graduation. Disaggregating the analysis by gender and family formation highlights that employment patterns vary among women by caregiving responsibilities. Previous studies have shown that ideal worker norms affect women with caregiving responsibilities more acutely, which may help explain these patterns (Hochschild, 1995; Lester, 2015; Ward and Wolf-Wendel, 2012, 2016; Williams, 2000). Examining the career paths of engineering PhDs long-term, research findings underscore that there is a tendency for this cohort of women to enter the workforce as time progresses. Their entry into the workforce appears to be primarily into the academic sector, compared to government or industry. Thus, academic institutions striving to increase the proportion of women among their engineering faculty have multiple opportunities to potentially recruit women engineering PhDs.

Limitations

There are multiple factors at the individual, organizational and environmental levels that intersect to influence the career paths of doctorates. As shown by Roach and Sauermann (2010), career interests contribute to a PhD's preference for an academic or science career. Kulp (2020) also illustrated how resources that PhD student mothers accumulate during doctorate education, such as funding for graduate study (fellowship, research assistantship, teaching assistantship or self-funded), are associated with the attainment of tenure track faculty positions. Meanwhile, Moen (2016) illustrated how norms regarding work and socialization into specific work roles can constrain women's and men's career trajectories. A

limitation of this study is that many of the variables that contribute to engineering doctorates' employment outcomes are not included in the analyses, leaving issues associated with omitted variables bias. The employment outcomes are also grouped by broad category, and there are differences and nuances among the different types of academic positions across different types of postsecondary institutions. The research findings are thus considered correlational, rather than causal. Nevertheless, the research findings provide important descriptive information for engineering PhDs and doctoral programs regarding long-term employment outcomes.

The findings also apply only to engineering PhDs who reside in the USA, as the survey waves (2001–2010) do not include PhDs working outside of the USA. More recent waves of the NSF SDR include data from PhDs working outside of the USA and can provide additional insights regarding mobility and international employment. The life course perspective provides insights regarding the relationship between having young dependents in the household at the time of PhD completion with long-term career outcomes. This is a very specific timing of family formation, and the analyses do not capture how career outcomes might differ if PhDs have older dependents at the time of PhD completion or if PhDs have young dependents after PhD completion. The life course perspective suggests that the timing of family formation at different stages of the life span may have distinct influences on career outcomes.

Figure 2 shows the trends in changes in the proportions of engineering PhDs participating in the different employment sectors over time. However, this descriptive analysis does not provide the reasons or causes for these employment changes or why women with young dependents at the time of PhD completion are out of the workforce. To an extent, this could signify constrained work choices and a combination of factors, including challenges exerted by ideal worker norms. It could also signal potential socioeconomic advantages that would accommodate the ability to be out of the workforce. Future work will investigate further why engineering PhDs transition into different employment sectors and examine more closely engineering PhDs' career-related choices at the intersection of gender and family formation through individual interviews.

Conclusion and implications

The research findings highlight the nonlinear career paths of engineering PhDs and illustrate the multiple transitions and permeability between employment sectors. They address the multiple calls for greater career transparency for PhDs and contributes to the occupational change literature. Using the life course perspective as a framework, findings show that women with young dependents at the time of PhD graduation are more likely to report not being in the labor force following PhD completion, but then enter the workforce as time progresses. Institutions aiming to increase the participation of women should consider policies and programs to facilitate this transition into faculty and other academic roles. The importance of work–life integration and work support for women has consistently been shown in previous studies (Mirick and Wladkowski, 2018; Springer *et al.*, 2009; Wladkowski and Mirick, 2020). Higher education administrators can apply these findings to help shape policies to encourage more women to pursue and complete engineering doctorates, to accommodate parenthood, to enhance programs and doctoral student socialization to alleviate challenges associated with ideal worker norms and to develop alternative career pathways to the professoriate across a greater time span following PhD completion. These support programs could entail offering funding for parental leave, providing greater access to child care centers and shifting the departmental culture to normalize parenthood during the pursuit of the PhD program.

The results also highlight that engineering doctorates change employment sectors, and that there is permeability between employment sectors. PhDs who intend to pursue tenure track faculty positions, but do not initially obtain a position upon PhD graduation, are faced with decisions regarding which positions may contribute to achieving their career goal. The results highlight that academic-related positions, such as postdoctoral training and other academic positions, compared to working in industry, are in greater alignment with entering the professoriate. Research findings provide prospective and current engineering PhD students with greater transparency regarding career opportunities and trajectories, as well as provide engineering programs with foundational knowledge to inform and enhance professional development programs for multiple employment sectors.

There are ongoing efforts to expand the training of PhD students for a wider range of careers, such as those supported by the National Institutes of Health Broadening Experiences in Scientific Training (NIH BEST) program (Lenzi *et al.*, 2020). The NIH BEST programs have been shown to shift their biomedical sciences graduate students' perceptions regarding the range of career opportunities available and instill greater confidence in pursuing nonacademic careers (Lenzi *et al.*, 2020). Organizations, such as the Society for Women Engineers and Women in Engineering Proactive Network, also support women's success in industry careers and engineering pursuits. Programs and organizations such as these could potentially help strengthen preparation for industry careers, which many engineering PhDs enter. Similarly, there are also a number of efforts aimed at preparing PhD students for faculty careers through mentorship, coursework, Web resources and related programs (Pruitt-Logan *et al.*, 2002; Winter *et al.*, 2018).

While this study focuses on the intersection of family formation and career trajectories among engineering PhDs, it also contributes to larger conversations regarding the long-term career paths of doctorates. The life course perspective highlights that employment patterns are not necessarily linear and that multiple entry points should be encouraged for a more diverse academic faculty. The findings highlight that there are opportunities for higher education administrators to increase diversity by shaping policies and programs to encourage multiple alternative career pathways to the professoriate. These in turn can help advance efforts to increase the participation of women in engineering fields. Key higher education administrators, policymakers and stakeholders could potentially apply the research findings toward developing strategies to broaden participation in engineering and to strengthen students' preparation for the multitude of nonlinear career paths.

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