Career Advancement Outcomes in Academic Science, Technology, Engineering and Mathematics (STEM): Gender, Mentoring Resources, and Homophily

by

Sang Eun Lee

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Approved November 2017 by the
Graduate Supervisory Committee:

Eric W. Welch, Chair
Mary K. Feeney
Elizabeth A. Corley

ARIZONA STATE UNIVERSITY

December 2017

ABSTRACT

This dissertation examines gender differences in career advancement outcomes among academic science, technology, engineering and mathematics (STEM) scientists. In particular, this research examines effects of gender, PhD advisors and postdoctoral supervisors mentoring resources and gender homophily in the mentoring dyads on the career advancement outcomes at early career stages.

Female academic scientists have disadvantages in the career progress in the academic STEM. They tend to fall behind throughout their career paths and to leave the field compared to their male colleagues. Researchers have found that gender differences in the career advancement are shaped by gender-biased evaluations derived from gender stereotypes. Other studies demonstrate the positive impacts of mentoring and gender homophily in the mentoring dyads. To add greater insights to the current findings of female academic scientists' career disadvantages, this dissertation investigates comprehensive effects of gender, mentoring, and gender homophily in the mentoring dyads on female scientists' career advancement outcomes in academic science.

Based on the Status Characteristics Theory, the concept of mentoring, Social Capital Theory, and Ingroup Bias Theory, causal path models are developed to test direct and indirect effects of gender, mentoring resources, and gender homophily on STEM faculty's career advancement. The research models were tested using structural equation modeling (SEM) with data collected from a national survey, funded by the National Science Foundation, completed in 2011 by tenured and tenure-track academic STEM faculty from higher education institutions in the United States. Findings suggest that there is no gender difference in career advancement controlling for mentoring resources and gender homophily in the mentoring dyads and other factors including research productivity and domestic caregiving responsibilities. Findings also show that the positive relationship between gender homophily in mentoring dyads and the reception of the mentoring resources, especially regarding providing help on career development and research collaboration, lead to enhanced early stage career advancement. Insights from the findings contribute both to theoretical understandings of the overall effects of gender, mentoring, and gender homophily in the mentoring dyads on female academic scientists' career advancement at early career stages and to provide evidence of positive effects of same-gender mentoring dyads to universities.

TABLE OF CONTENTS

CHAPTER Page

CHAPTER Page

CHAPTER Page

CHAPTER Page

CHAPTER Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

Figure Page

1. Introduction

1.1. Research background

In summer 2017, three senior female academic scientists filed lawsuits against their institution to claim pervasive and long-standing gender discrimination (Wadman, 2017a). They alleged that their institution has paid female scientists less, “disparaged female scientists’ work, shut them out of advancement opportunities, pressured them to shrink their labs, and prevented them from being considered for lucrative grants” (Wadman, 2017a, p. 238). In particular, the complaints told that they had been excluded from the institution funding while other labs run by male faculty members received most of it. They also alleged that no female professor had earned tenure and promotion to associate professor since 1999. At a similar time, a memo written by a male engineer in Silicon Valley ignited a firestorm of debates about gender discrimination and got him fired subsequently. In the memo, he argued that gender differences in the tech industry including women's underrepresentation have to do with ‘biological causes' (Wakabayashi, 2017). These two cases – fighting against gender discrimination and exposing gender biased perception – help motivate this dissertation that aims to explore gender differences in career advancement of academic science, technology, engineering and mathematic (STEM) faculty.

Female academic scientists tend to be marginalized and to fall behind throughout their career paths (National Research Council [NRC], 2010; Williams, 2000). Female scientists are underrepresented in tenure-track professor positions in academic science. Although the number of female scientists with science and engineering doctorate degrees increased over time, the number of female assistant professors in the field is not represented proportionate to the number of doctorates women earn. Studies also show that the percentage of female faculty decreases at higher ranks, which may indicate that female scientists leave the tenure-track academic career path instead of advancing to the next level or that they are not promoted. The career path in academic science is generally conceptualized as a ‘pipeline’ comprised of the series of linear including receiving PhD, completing postdoctoral training, obtaining an assistant professor position, undergoing a probationary pre-tenure period, earning promotion to associate professor and receiving tenure, and earning promotion to full professor (Lundquist & Misra, 2015; Morgan, Gelbgiser, & Weeden, 2013; Wolfinger, Mason, & Goulden, 2009). Given the concept of a career pipeline, female scientists’ leaving the field at every career stage is referred to as ‘leakage.’ Female scientists who leak out of the academic career pipeline may settle for temporary or non-tenure-track faculty positions that are identified as less prestigious and have lower job security and salary (Curtis, 2011).

In addition to leaving the tenure-track academic career in the STEM field, it takes longer for female academic scientists to make progress to the next career stage. In fact, studies show that it takes longer for women to complete doctoral degrees (Thurgood, Golladay, & Hill, 2006), to obtain permanent and secure faculty positions in academia (Ginther & Kahn, 2006) and to earn promotions (Krefting, 2003; Misra et al., 2011; NRC, 2010). Delayed career progress is associated with several critical negative implications such as lower job security and lower salaries (Gardner & Blackstone, 2013; Long, Allison, & McGinnis, 1993; NRC, 2010; Perna, 2001) and lower scholarly autonomy in research or opportunities for specialization (Dietz & Bozeman, 2005; Smith-Doerr, 2006), which can result in increased stress and anxiety (Toren, 1993) and lower work satisfaction (Lawrence, Celis, & Ott, 2014). To address the question why it takes longer for female scientists to make progress in their academic career paths, research has attempted to explain it as a function of lower productivity or competence because academic hiring and promotion decisions are primarily based on scholarly productivity. However, recent studies have found that females are neither less productive nor less competent than males (Ceci, Ginther, Kahn, & Williams, 2014; Feeney & Welch, unpublished manuscript). Thus, recent studies pay more attention to sexism and implicit gender bias to explain the mismatch between the gender-neutral productivity and gender-biased career advancement outcomes.

1.2. Research motivation

Female scientists' disadvantages in the career progress in academic STEM motivate this study. The first motivating factor for this dissertation is associated with the need to understand gender effects on academic STEM scientists' career advancement outcome. More precisely, corresponding to the literature about the gender inequality in the workplace, this dissertation addresses the gender effects that are shaped by gender-bias perceptions. Theories explaining gender inequality in career advancement suggest that gender biases derived from gender stereotypes lead evaluators to make gender-biased decisions during the evaluation processes (Bodenhausen, Macrae, & Garst, 1998; Reskin, 2000a, 2000b). Gender bias tends to be more salient in the context where stereotypically masculine attributes are highly valued, for example, in the traditional male-dominated occupation such as academic science (Ridgeway & Correll, 2004). As briefly mentioned in the previous section, most studies about gender inequality in workplace focus on sexism and subtle gender bias. However, little empirical research has been undertaken to investigate the gender differences in academic STEM scientists' career advancement outcomes, which are affected by gender stereotypes.

The second motivation of this dissertation stems from the first. Not only has research provided little empirical evidence of the gender difference in academic STEM advancement, but also there has been little research conducted to examine the gender differences regarding the extent of delay in career advancement. Most studies exploring the gender difference in career advancement outcomes have focused on the probability of female scientists getting hired or promoted rather than the extent of time for female academic scientists to get hired or earn promotion. As presented in the previous section, studies acknowledge that female scientists disproportionately 'leak out' of the tenure-track academic career pipeline. Moreover, earlier stages of the career path including initial academic job appointments are key junctures where leakage is more likely to occur (Winslow & David, 2016). However, little research has addressed whether the female scientists who 'leak out' of the tenure-track academic career pipeline leave academia for good or remain in the field as part-time instructional staff positions or full-time non-tenure-track positions until they get the full-time tenure-track position. Therefore, this study is motivated by the need to explore female academic scientists who are 'clogged' in the academic pipeline instead of leaking out of it.

The third reason for the scholarly interest of this dissertation is the opportunity to investigate the role of mentoring in advancement delay. As in other career fields, mentor-mentee relationships in academic settings provide mentees, the junior persons in the fields, career-related and psychosocial help and support (Durley, 2006; Kram, 1985) for mentees' career development and advancement in the field. Faculty mentors provide mentees challenging work, networking opportunities, sponsorship, and advocacy that aim at career development. Faculty mentors also provide psychosocial support such as counseling, friendship, advice on collegial interactions, and role modeling. Research on the mentoring effect on academic faculty members' career development and progress has surged in the past several decades. Studies present evidence of positive effects of mentoring on graduate students' program completion and research productivity (Austin & McDaniels 2006; Lovitts, 2001; Nettles & Millett, 2006), as well as on academic faculty members' job satisfaction (Ingram et al., 2009). Despite the surging theoretical and empirical studies about the significant mentoring effects, study contexts tend to be limited to those who are currently in graduate programs or who have already obtained tenure-track or tenured positions. Indeed, less is known about how mentoring affects junior scholar career advancement at transition points in the academic career.

The fourth motivating factor for this dissertation is associated with gender homophily in mentoring relationships. In particular, this dissertation seeks to investigate the extent of mentoring resources that female academic scientists receive from female mentors. Both theoretical and empirical studies have demonstrated that female mentees receive more psychosocial support from female mentors (Schroeder & Mynatt, 1999; Sosik & Godshalk, 2005). Studies also emphasize the importance of female-female mentoring relationships in where male-dominated culture is pervasive like the academic science. Based on the perceived similarity and interpersonal comfort, same-gender mentoring dyads for females may provide female mentees more opportunities to discuss work-life balance, educational climate, performance expectations, and how the senior female professionals have broken down gender barriers throughout their career (Chesler, Boyle Single, & Mikic, 2003; Brainard & Ailes-Sengers, 1994; Brainard & Carlin, 1998; Clewell & Campbell, 2002). In comparison, male mentors may offer access to men's networks in these male dominated fields. There is lack of empirical consensus on the beneficial effects of gender homophily in mentorship for female mentees. Thus, this dissertation is motivated by the need to explore both instrumental and psychosocial mentoring via the same-gender mentoring dyads, and this effect on female academic scientist career advancement outcomes.

1.3. Research Questions

Based on the aforementioned research background and motivations, the following primary research questions will be addressed: (1) Does gender affect the career advancement outcomes for academic STEM scientists?; (2) Does the provision of mentoring resources (as part of job seeking and otherwise) affect academic STEM scientists' career advancement outcome?; (3) Do female STEM scientists receive more mentoring resources from female mentors?; and (4) Does the same-gender mentoring dyads affect the career advancement outcome for academic STEM scientists?

The overall argument in this dissertation is that the gender bias contributes negatively to career advancement outcomes for academic STEM scientists. Also, this study argues that female scientists are disadvantaged in receiving mentoring resources that are crucial for scholarly development and career progress. The last core argument is that the gender disparities in career advancement and mentoring resources can be alleviated through the same-gender mentoring dyads because female junior scientists can receive more help and support from same-gender mentors. These arguments provide foundations on which I build my theoretical model and hypotheses.

1.4. Contribution of this study

This dissertation makes several contributions. First, this dissertation applies insights of status characteristics theory to account for gender effects. In particular, status characteristics theory is used to account for the gender differences in STEM scientists' career development outcomes. Status Characteristics Theory (SCT) provides a foundation for understanding how gender biased perceptions result in biased career advancement outcomes among academic STEM scientists. SCT's' key principle explaining such gender-biased career advancement outcome is that female scientist and their work are evaluated in a biased way. Gendered evaluations occur because female scientists are perceived to be less productive, less competent, or less fit, as compared to their male colleagues, in the academic STEM in where attributes represented as highly valued worker qualities in academic science are less likely to be associated with female gender. By using the status characteristics theory to examine gender effects on academic STEM scientists' career development outcome, this dissertation contributes and extends emerging literature that focuses on understanding how the gender biased perception casts female scientists as not fitting the field, which results in adverse career advancement outcomes for female scientists.

Second, this dissertation addresses the limitations of current research on gender differences in the career progress in academic science. While prior studies have mainly addressed why the ‘leakage' in the academic science career pipeline occurs, little research has addressed the ‘clog' in the pipeline regarding delays in career advancement. Moving to the next stage in academic career may be an outcome of the integrated effects of each job candidate’s personal traits, scholarly achievements, and mentoring help and support. This dissertation makes an empirical contribution to the literature on gender differences in career progress in academic science by providing empirical evidence of how much each of these factors affects gender differences in academic career advancement.

Third, this dissertation will address the limitations of existing research about the mentoring effects on the career advancement outcome in academic science. In particular, this study focuses on junior scientists’ mentoring relationships with their PhD advisors and postdoctoral supervisors because PhD advisor-advisee and postdoctoral supervisors-supervisee relationships are the most common mentoring relationships that junior scientists are involved in. When it comes to the mentoring of PhD advisors, existing studies largely focus on graduate student degree completion and their research productivity. Moreover, there are even less empirical research made to explore the effects of postdoctoral supervisor mentoring on junior scholar career advancement. Thus, by examining how mentoring from PhD advisors and postdoctoral supervisors, this dissertation contributes and extends the literature on the concept of mentoring.

Fourth, this research adds to the literature on gender homophily in mentoring dyads. The literature often pays more attentions to the beneficial effects on mentees' career success and fewer attentions to the extent of how the positive effects of the gender homophily in mentoring dyads alleviates gender difference in career advancement outcomes. Thus, this dissertation offers more a comprehensive understanding of collective effects of gender homophily and the gender bias on junior academic scientists' career advancement outcome.

1.5. Organization of this study

This dissertation is organized into six chapters. Chapter 2, the literature review, starts with a general overview of the gender disparities in academic STEM fields focusing on female scientists' underrepresentation at the faculty level and their delayed career advancement. Following this, the Status Characteristics Theory (SCT) is presented to explain the gender disparity in career advancement in the academic STEM. In doing so, it is discussed what causes the disparities and how the causes can be viewed through the lens of SCT. The discussion then turns towards the mentoring from PhD advisors and postdoctoral supervisors who are key persons who provide such resource to junior STEM scholars. Social Capital Theory is used to account for positive impacts of mentoring support and advice from Ph.D. advisors and postdoctoral supervisors on junior scientists' career advancement outcome. Ingroup Bias Theory (IBT) is also used in Chapter 2 to explain gender homophily in mentoring dyads and higher mentoring resource provision between same-gender mentoring dyads in the academic STEM. IBT argues that individuals intuitively feel close to those who are similar to them.

Chapter 3 presents the proposed hypotheses that integrate the concepts and theories reviewed in chapter two. There are two sets of hypotheses to test gender effects. One is to test gender effects on academic STEM scientists' career advancement outcomes, and the other is to test gender effects on mentoring resources from PhD advisors and postdoctoral supervisors. Additionally, hypotheses to test the effects of mentoring resources from PhD advisors and postdoctoral supervisors on the career advancement outcome are developed. Two more sets of hypotheses are developed to examine gender homophily effects in the creation of same-gender mentoring dyads and mentoring resource provision in the same-gender mentoring dyads. The last set of hypotheses developed in this chapter is to examine the indirect effects of gender on academic STEM scientists' career advancement outcome through the creation of same-gender mentoring dyads and mentoring resource provision in the same-gender mentoring dyads.

Chapter 4 describes the data and methodology for this research. Data for this dissertation is from a NSF-funded national online survey targeting academic faculty members in four STEM fields of biology, biochemistry, civil engineering, and mathematics respectively. The survey collects a wide range of information about academic STEM faculty, including their personal and professional background, productivity, teaching and research activities, workplace satisfaction, networks, and perceptions of their work environment. Explanations about the variables and descriptions of the measurement are provided. After that, this chapter discusses how missing data is handled: the extent and pattern of the missing data and techniques for handling the missing data. Finally, this chapter discusses the Structural Equation Modeling (SEM) used for the data analysis.

Research findings are presented in Chapter 5. This chapter starts with the presentation of empirical models. Next, the descriptive statistics of the sample to illustrate the distribution of the data is presented. Following the descriptive statistics, SEM model results are presented to determine the main effects of gender, mentoring resources from PhD advisors and postdoctoral supervisors, gender homophily on academic STEM scientists' career advancement outcome are presented. Robustness checks are conducted to test the validity of the results.

In Chapter 6, the findings in detail and highlight the theoretical and practical contributions of the research are discussed. The limitations and the future research directions are discussed in the final chapter.

2. Literature Review

2.1. Introduction

The overall argument of this study is that there are gender differences in academic STEM scientists’ career advancement outcome at early career stages. This study also argues that mentoring would have positive impacts on the career advancement outcome. This chapter, in particular, aims to develop a foundation to understand how gender and mentoring influence academic STEM scientists’ career advancement outcome. What follows is a layout of the five main goals that the chapter aims to achieve.

First, this chapter presents an overview of the Status Characteristics Theory (SCT) to explain gender differences in academic STEM scientists’ career advancement outcome. SCT's' key principle explaining the gender difference in STEM scientists’ career advancement outcome is gender stratification. SCT accounts for gender differences in the workplace as an outcome of gender-biased evaluation associated with gender-biased job performance and commitment expectation, which is rooted in gender stereotypes. Such gendered evaluations occur because attributes represented as highly valued worker qualities in academic science are less likely to be associated with female scientists. Thus, according to SCT, female academic scientists tend to have disadvantages in career advancement outcomes as they receive unfavorable evaluation outcomes at each transition point in their academic career.

Second, the concept of mentoring explains the role of Ph.D. advisors and postdoctoral supervisors as mentors who provide support and assistance to their mentees. Mentoring refers to “an intense, dyadic relationship in which a more senior, experienced person, called a mentor, provides support and assistance to a more junior, less experienced colleague, referred to as a protégé or mentee" (Hezlett & Gibson, 2007, p. 385). Faculty mentors in academic settings provide mentees instrumental functions of mentoring (Durley, 2006; Kram, 1985) such as providing opportunities for challenging work, networking opportunities, and advocacy that aim at career development. Faculty mentors also provide psychosocial support (Durley, 2006; Kram, 1985). Examples of psychosocial support from mentors include providing acceptance, friendship, advice on collegial interactions, and role modeling.

Third, Social Capital Theory is used to illustrate effects of the mentoring resource from PhD advisors and postdoctoral supervisors on junior academic STEM scientists' career advancement outcome. The general definition of social capital is "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition" (Bourdieu, 1985, p. 248). Studies provide empirical findings supporting that social capital is associated with enhanced career advancement outcomes including getting a better job, early promotion, and higher compensation (Forret & Dougherty, 2004). Given that the definition of social capital encompasses individuals' social relationships and positive outcomes stemming from the relationships, social capital is well aligned with the concept of mentoring. This dissertation captures capturing two components of mentoring: the relationship and resource provision within the relationship. Thus, Social Capital Theory can provide insights for understanding beneficial impacts of mentoring support and advice provided Ph.D. advisors and postdoctoral supervisors on junior scientists' career advancement.

Fourth, this section addresses a question of whether and to what extent junior scientists' gender has an impact on the receipt of mentoring help and advice, which in turn influences their career progress. Incorporation of Status Characteristics Theory and the concept of mentoring provide insights for understanding combined effects of gender and mentoring on junior scientists' career progress.

Fifth, Ingroup Bias Theory (IBT) is employed to account for both gender homophily in mentoring dyads and higher mentoring resource provision in the same-gender mentoring dyads in the academic STEM. IBT argues that individuals intuitively feel close to those who are similar to them (i.e., ingroup members). Both from mentee's and mentor's perspective, such closeness and fondness lead them to generate same-gender mentoring dyads and to provide favorable evaluations and treatments in such mentoring dyads (Brewer, 1979, 1999, 2007; Hewstone et al., 2002). The preferential treatments among the ingroup members include providing more resource and help (Chen & Li, 2009) and giving less punishment (Mussweiler & Ockenfels, 2013).

This chapter ends with a conceptual model illustrating relationships between gender, network resource, gender homophily, and time to obtain tenure-track positions among STEM faculty.

2.2. Gender disparities in academic STEM

In the early 1990s, The Massachusetts Institute of Technology (MIT) published a report about female scientists' status in academic science (MIT, 1999). The report demonstrated that gender discriminations pervasively exists in academic science, which results in gender inequalities in career advancement outcomes including salary, grants, faculty ranks, and having leadership positions (MIT, 1999). The report increased the awareness of female academics' disadvantages in career advancement outcomes and evoked considerable movements to address the issue of gender inequity in academia. However, obvious disadvantages of female academic scientists have consistently occurred. For example, three senior female academic scientists recently filed lawsuits against their institution to complain of long-term gender discrimination (Wadman, 2017a). They allege that tenured female professors in the institution including them have been treated as "second class citizens" (Lundblad, 2017, p. 4). Particularly, the female scientists as plaintiffs of the lawsuit claimed unlawful employment practices. In the lawsuit, they describe explicit and implicit gender discrimination as following. First, female scientists are not only underrepresented at the higher ranks but also excluded from career advancement opportunities. There are 28 male full professors with tenure while there are only four female full professors. Second, the institution does not make fair decision making about "compensation, individual laboratory support, and leadership opportunities" (Lundblad, 2017, p. 4) because the institution lacks "written guidelines or information detailing compensation … distribution of laboratory space and other resources" (Lundblad, 2017, p. 4). The female scientists who filed the lawsuit alleged that these are the reasons for female faculty members' lack of career advancement opportunities or receiving institution-funded grants, which causes pressures for female faculty members to shrink their labs. Third, the institution is alleged to allow the 'old boys club' culture that is referred to the hostile work environment for female faculty members. For example, there are fewer newly hired female faculty members as compared to men, and there is no female professor who earned tenure and promotion to associate professor since 1999 (Lundblad, 2017). Indeed, the lawsuit and the plaintiffs' arguments well capture the gender disparity in the academic STEM that is the background of this study.

2.2.1. Underrepresentation of female scientists at faculty level

At universities, one of the most prominent forms of disadvantages that female scientists experience is that they are underrepresented in tenure-track professor positions in academic science. The National Science Foundation (NSF) reports information of science and engineering faculty rank. In 2013, female faculty members comprised of 45% of tenure-track assistant professors, 38% of associate, and 24% of full professors in the science and engineering fields (NSF, 2016). This data is an evidence of female scientists' underrepresentation at the faculty level because their representation is not matched by the recent gains in the number of female doctorate recipients. The number of female scientists with science and engineering doctorate degrees has increased over time. In Engineering, the percent of female doctorate recipients was just over 1% in 1974 (Ginther & Kahn, 2006). It increased to 39% in 2000 and 45% in 2013 (NSF, 2016). The percentage of doctorates awarded to females in Life Sciences (relatively non-math intensive fields in the academic STEM) increased from about 20% in 1974 (Ginther & Kahn, 2006) to nearly 50% in 2004 and 56% in 2013 (NSF, 2016).

NSF's data also show that the percentage of female faculty decreases as they promote to higher ranks, which may be evidence of the gender inequality in career advancement. In other words, at each transition point in the academic career, a lower proportion of female scientists moves to the next milestone as compared to their male colleagues. It may indicate that female scientists leave the tenure-track academic career path instead of advancing to the next level or that they get stuck. The academic career is generally conceptualized as a ‘pipeline’ (Lundquist & Misra, 2015; Morgan, Gelbgiser, & Weeden, 2013; Wolfinger, Mason, & Goulden, 2009). The series of orderly steps include receiving PhD, completing postdoctoral training, obtaining assistant professor position, undergoing a probationary pre-tenure period of about 5 or 6 years, earning promotion to associate professor as receiving tenure, and earn promotion to full professor (Lundquist & Misra, 2015; Morgan, Gelbgiser, & Weeden, 2013; Wolfinger, Mason, & Goulden, 2009). Studies have long recognized that there is a ‘leak’ in the academic pipeline; it loses female scientists at every career stage. The flow of ‘leaked’ female faculty members reaches to temporary or non-tenure-track faculty positions (Adamowicz, 2017; Rosser & Taylor 2009; Turk-Bicakci, Berger & Haxton, 2014) that are identified as less prestigious or less appealing in terms of job stability and salary (Curtis, 2011). Otherwise, female faculty members find non-academic scientist positions in industry, government, nonprofit organizations or even leaving science altogether (Adamowicz, 2017; Rosser & Taylor, 2009; Turk-Bicakci, Berger & Haxton, 2014).

2.2.2. Delayed career advancement for female scientists start at each transition point in the academic career

For female scientists who proceed with the tenure-track academic career instead of moving out of academia, their underrepresentation at faculty level also indicates gender inequality in career advancement in the way of taking more time for the female to move to the next stage.

Studies support the idea of delays in career progress for female academic scientists. At the graduate level, Thurgood, Golladay, & Hill (2006) show that it takes slightly longer for female students to complete their degrees than their male counterparts. Female academic scientists take more time to obtain permanent and secure faculty positions in academia (Ginther & Kahn, 2005). After obtaining tenure-track assistant professor positions, female scientists stay at the rank longer than males. The National Research Council (2010) reports that it takes nine years for women in STEM fields to receive tenure on average as compared to 7.6 years for men. Longer time to tenure further disadvantages female academic scientists because delayed tenure is associated with several important negative implications such as lower job security and lower salaries (Gardner & Blackstone 2013; Long, Allison, & McGinnis, 1993; National Research Council, 2010; Perna, 2001), which can result in increased stress and anxiety (Toren, 1993) and lower work satisfaction (Lawrence, Celis, & Ott, 2014). Achieving promotion to full professor is also slower for female faculty members (Krefting, 2003; Misra et al., 2011).

To address the question why it takes longer for female scientists to move to the next stage in their academic career path, studies have explained the gender difference in career advancement outcome as a function of lower productivity or competence (Newman, 1994). It is because faculty hiring and promotion decisions in academia are largely based on scholarly productivity. However, recent studies show that female scientists are neither less productive nor less competence than male counterparts (Ceci, Ginther, Kahn, & Williams, 2014; Feeney & Welch, unpublished manuscript). Thus, studies focus on sexism and subtle gender bias to explain the mismatch between the gender-neutral productivity and gender differences in career advancement outcome.

The following section presents some explanations of gender inequality in career advancement in academic STEM relying on subtle gender bias and discrimination as applying Status Characteristics Theory.

2.3. Status Characteristics Theory: Explaining gender disparity in career advancement in academic STEM

To explain gender effects on junior STEM scholars' career advancement outcomes, Status Characteristics Theory (SCT) is applied. In particular, SCT's descriptions of gender as status characteristic captures how female academic scientists, as compared to male scientists, tend to be perceived as less fit or having an inferior status in academic science.

SCT argues that social groups, as nominal distinctions, become stratified or 'status characteristic' when they are associated with widely held perceptions and beliefs (Berger, Fiske, Morman, & Zelditch, 2015; Correll & Ridgeway, 2003; Correll & Benard, 2006). For example, gender gets a 'status characteristic' as being female or male is associated with pervasive gender stereotypes. In most labor market settings, attributes represented as highly valued worker qualities are often associated with male workers. The male gender is generally considered to have attributes such as being task-oriented, dominant, confident, ambitious, independent, and logical (Eagly & Karau, 2002; Heilman, 2012), while the female gender is believed to be associated with communal attributes such as being caring, helpful, kind, considerate, nurturing, perceptive, understanding, and affectionate (Eagly & Karau, 2002; Heilman, 2012). Especially in a traditionally male-dominant field such as academic science, such gender stereotypes create gender-biased perceptions that female academic scientists do not perform well because attributes expected for female gender do not accord with the perceived attributes required to succeed in the field (Heilman, 2012). Consequently, female gender becomes viewed as less fit or as having inferior status in the labor markets due to the discrepancy between female gender stereotypes and attributes represented as highly valued qualities for workers in the labor market.

In sum, SCT's key principle explains gender as a status characteristic in the labor market especially where male-dominated culture is pervasive in gender-biased perceptions. In the following part, detailed discussions of how the gender-biased perceptions cause gender disparities in career advancement outcome and, more specifically, career advancement in academic science.

2.3.1. Causes of disparities: *gender-biased performance and commitment expectations*

As briefly discussed above, SCT accounts for how gender stereotypes generate perceptions that male workers achieve better than females in work settings. Studies support the idea of the association between gender stereotype and gendered performance expectation (Correll & Benard, 2006; Heilman, 2012). Heilman (2012, 2015) articulates how descriptive and prescriptive gender stereotypes produce gender-biased performance expectations among evaluators and how the expectations lead to disadvantages for female workers' career progress. Descriptive gender stereotypes promote gender bias because of negative performance expectations that are shaped by the perception that the female stereotypes do not fit the attributes needed to succeed in the male gender-typed field (Heilman, 2012). Prescriptive gender stereotypes generate normative standards of what female ‘should be/do’ or ‘should not be/do’ (Heilman, 2012). If female workers are perceived not to behave as they are expected to, it prompts the evaluators’ disapproval and negative performance expectations toward female workers.

As job performance expectations are gender-biased, SCT argues that commitment expectations are also gendered. Female workers tend to be perceived to exert less effort at work than male counterparts (Correll & Benard, 2006) regardless if it is true or not. Women are conventionally expected to take domestic caregiver roles, including getting married, having children, and being committed to childcare (Leahey, 2006; Ward & Wolf-Wendel, 2004). Because of such expectations, women, in general, are often perceived as not fully committed to their professional careers (Gupta, Kemelgor, Fuchs, & Etzkowitz, 2005). They are perceived to have “less time, energy, and commitment to invest in their professional careers” since caregiving duties exhaust their time (Toren, 1993, p. 439).

2.3.2. Causes of disparities: *Gendered evaluations based on gendered performance expectations*

The literature on gender bias in workplace supports SCT’s arguments that gender-biased performance and commitment expectations lead to biased evaluations. Biased performance expectations result in uncomplimentary evaluations of female workers because their job performance outcomes continue to be overlooked or undervalued (Long & Fox, 1995; Heilman & Haynes, 2005; Inesi & Cable, 2014; Rossiter, 1993; Wennerås

& Wold, 2001). O'Leary & Wallston (1982) present evidence supporting gender-biased performance evaluation. Both men and women are found to devalue women's work more than men's when they are aware of the gender of those evaluated; however, there was no difference in evaluation results when gender is unknown (O'Leary & Wallston, 1982). More studies supported that evaluation outcomes are gender-biased. Academic researchers tend to recall lower publishing (Cole & Zuckerman, 1984; Long, 1978; Toutkoushian & Bellas, 1999) for female academic scientists than male scientists because they are more likely to remember information that is consistent with expectations including gendered stereotypes while they more readily forget information that is not (Heilman, 2012, 2015). Also, female engineers are more likely to be interrupted while they are presenting their work at job interviews so that they have less time to reach to the conclusion of their talks because they face stricter standards when they are evaluated (Blair-Loy, Rogers, Glaser, Wong, Abraham, & Cosman, 2017). In sum, given that workers' expected future performance and job commitment can also take effect in the evaluation process (Correll & Benard, 2006) in hiring and promotion, female scholars who are perceived to have lower job performance and commitment may have disadvantages in career progress. Due to biased evaluations female workers need to achieve more in order to be seen as qualified as their male counterparts (Bilimoria, Joy, & Liang, 2008; Drago et al., 2006).

2.4. Summary: *Status Characteristics Theory*

Status Characteristics Theory (SCT) explains gender differences in junior STEM scholars' initial career appointment outcomes. According to SCT, gender stereotypes shape gender-biased performance expectations and evaluations. Female scientists are perceived as of relatively inferior status or second-rate group in academic science; male scientists are more suitable in academic science, and their work is more positively evaluated than equally qualified women (Correll & Benard, 2006; Ridgeway & Correll, 2004; Ridgeway & Smith-Lovin, 1999; Wagner & Berer, 1993), SCT also discusses that gender-biased evlosealuation is rooted in gender-biased job performance and commitment expectations that are shaped by gender stereotypes. Consequently, the gender-biased evaluation would lead to negative outcomes for female scientists during career advancement stages.

However, SCT can only be a partial foundation for understanding gender disparities in early career progess outcomes in academic STEM because gendered evaluation is one of the several important factors that determine such outcomes. Moreover, it is argued that gender-biased performance expectations and evaluations are also factors that contribute to the extent to which junior STEM scholars build their research skills and productivity before going to the job market, as well as when they are being evaluated in the hiring process.

The next section expands the theoretical framework through the review of mentoring. It will discuss how mentoring and social capital influence female scientists' career advancement outcomes in academic science. In particular, help and advice from PhD advisors and postdoctoral supervisors in mentoring relationships and the effects of such mentoring help and advice on career advancement will be discussed. Then both SCT and mentoring will be applied to explain gender differences in mentoring resources, which result in gender differences in academic STEM scientists' career advancement outcomes.

2.5. Mentoring, PhD advisors and postdoctoral supervisors

Mentoring addresses how support and help from mentors influence junior scientists' build their research skills and productivity, which in turn influences career advancement outcomes in academic science. In particular, the concept of mentoring is used in this part to account for the role of Ph.D. advisors and postdoctoral supervisors as mentors who provide support and assistance to their mentees and the impacts of such support and advice on junior scientists' career advancement.

2.5.1. Mentoring

Many studies have explored mentoring and its effect on different organizational settings and different types of interpersonal relationships.

Kram (1988), one of the most cited scholars in mentoring studies, conceptualizes the mentoring relationship as "a relationship between a young adult and an older, more experienced adult that helps the younger individual learn to navigate in the adult world and the world of work (p. 2). Kram (1988) describes the role of mentors as "a mentor supports, guides, and counsels that young adult as he or she accomplishes this important task" (Kram, 1988, p. 2). Kram (1988) elaborates the role of mentors by presenting two categories of mentoring functions: career-related and psychosocial mentoring function. The career-related mentoring function directly assists mentee's career development and advancement, which includes providing challenging tasks, coaching, sponsorship, and directly assisting mentees' career advancement (Kram, 1988). On the other hand, psychosocial-related mentoring function, which includes counseling, friendship, and role modeling, improves mentees' sense of identity and self-esteem in the career setting. Hezlett & Gibson (2007) provide a definition of mentoring that is quite similar to that of Kram (1988). Mentoring is "an intense, dyadic relationship in which a more senior, experienced person, called a mentor, provides support and assistance to a more junior, less experienced colleague, referred to as a protégé or mentee" (Hezlett & Gibson, 2007, p. 385). The noticeable difference between two definitions is the nature of actors who are involved in the relationship. While Kram's definition has an age component by denoting that a mentoring relationship is comprised of a younger and an older adult, Hezlett & Gibson's (2007) definition does not include the age component. Instead, they describe that mentoring relationship is comprised of two individuals who are less and more experienced. Eby (1997) also presents a frequently cited definition that underlines mentoring function and purpose. Eby (1997) defines mentoring as "an intense developmental relationship whereby advice, counseling, and developmental opportunities are provided to a protégé by a mentor, which, in turn, shapes the protégé's career experiences" (p. 126). Bozeman and Feeney (2007) provide an extensive review of studies on the topic of mentoring and develop two sets of definitions as employing several key principles of the concept of mentoring presented by other studies. Their mentoring definitions clarify actors, functions, and purposes of mentoring. Bozeman and Feeney's (2007) define mentoring as "a process for the informal transmission of knowledge, social capital, and psychosocial support perceived by the recipient as relevant to work, career, or professional development" (p. 731). Also, mentoring "entails informal communication, usually face-to-face and during a sustained period of time, between a person who is perceived to have greater relevant knowledge, wisdom, or experience (the mentor) and a person who is perceived to have less (the protégé)" (Bozeman & Feeney, 2007, p. 731).

2.5.2. Mentoring in the academy

Similar to mentor-mentee relationships in other career fields, faculty mentors in academic settings provide mentees with career-related and psychosocial support (Durley, 2006; Kram, 1985). Faculty mentors provide mentees challenging work, networking opportunities, sponsorship, and advocacy that aim at career development. Faculty mentors also provide psychosocial support such as counseling, friendship, advice on collegial interactions, and role modeling.

In academic settings, mentors are not necessarily the mentees' academic advisors. Mentors can be any faculty member either in or out of their department or university. Moreover, mentees can have a mentor who is outside of their field. Some studies (e.g., Creighton, Creighton, & Parks, 2010; Waldeck et al., 1997; Zhao, Golde, & McCormich, 2007; Hawley, 1993; Lyons et al., 1990; Nettles & Millet, 2006; Sosik & Godshalk, 2005; Muschallik & Pull, 2016) distinguish the terms by emphasizing the distinctive aspects of advisors and mentors. Others use the term advisors and mentors interchangeably (e.g., Crookston, 1972; Monsour & Corman, 1991; Paglis, Green, & Bauer, 2006; Wrench & Punyanunt, 2004) such that PhD advisors and postdoctoral supervisors serve as mentors to their advisees and supervisees.

Although studies acknowledge that advising and mentoring is conceptually distinctive, they also designate the overlap between functions of mentor and advisors

(Schlosser et al., 2003; Schlosser & Foley, 2008). As referring the mentors who are mentees' academic advisors to 'supervisory mentors,' studies have examined the extent of mentoring functions and outcomes between the supervisory mentors and non-supervisory mentors. Studies found that supervisory mentors provide more interpersonal comforts (Mullen, 1994) and attention (Ragins, 1997). Besides, other studies demonstrate that mentees who have supervisory mentors showed better career development outcomes than those who have non-supervisory mentors (Tepper, 1995; Fagenson-Eland et al., 1997).

In line with the preceding literature on supervisory mentors, this study focuses on supervisory mentoring in academic science. In particular, the function of mentoring by PhD advisors and postdoctoral supervisors and its effects on mentees' career advancement outcome will be discussed.

2.5.3. PhD advisors as mentors

As defined in the previous section, mentoring is a one-on-one relationship in the workplace, aims to enhance the work, career, and professional development of the mentees by support and help from mentors who are more experienced in the work settings.

PhD advisors, often referred to as advice providers, consultants, and counselors (Goldberg, 2003), can be reliable resource providers for PhD students to complete their degree programs. Schlosser, Knox, Moskivitz, & Hill (2003) define that academic advisors as "the faculty members who have the greatest responsibility for helping guide the advisee through the graduate program" (p. 179). Ph.D. advisor-advisee relationship is the most common mentoring relationship that graduate students are involved in (Waldeck et al., 1997). As mentors in other workplace settings do, PhD advisors provide career-related and psychosocial mentoring resource to their students.

Serving as students' primary contact point among faculty members in their programs (Weil, 2001), advisors are generally expected to perform specific mentoring functions such as providing instrumental information on programs and degree requirements, engaging students in research activities, and monitoring advisee progress (Brown, Daly, & Leong, 2009; Gelso, 1993; Johnson, 2007; Schlosser, Lyons, Talleyrand, Kim, & Johnson, 2011). Advisors' assistance is essential for students to "acquire the knowledge and independent research skills" (MacDonald et al., 2009, p. 6). Beyond the degree completion, advisor support helps determine employment opportunities by providing support on job search and job placement such as writing recommendation letters, making phone calls, or giving advice on negotiating. Support regarding job searching can develop PhD students' marketable skills and abilities (Barnes & Austin, 2009). Accordingly, PhD advisors' support ultimately determines employment opportunities (Barnes & Austin, 2009; Platow, 2012) in ways that enhance students' research skills and productivity and provide instrumental help with job searching and negotiating.

Along with such instrumental support related to student program completion and research productivity, PhD advisors also provide psychosocial support. PhD advisors act as a gateway for doctoral students to socialize to their program as well as their disciplines (Austin & McDaniels 2006; Lovitts 2001; Nettles & Millett, 2006). Lovitts' (2001) research on doctoral attrition indicated that PhD advisors significantly influence doctoral students' understanding of their discipline, their role and responsibilities as academic professionals, as well as their socialization as instructors and researchers. In particular, PhD advisors' psychosocial support has great impact when doctoral students struggle. Ahern & Manathunga (2004) argue that PhD advisors serve as 'clutch starters' for their stalled students. As mentioned above, for doctoral students, their PhD advisors are the primary contact point. PhD advisors are the ones with whom doctoral students work closely, as such, the PhD advisors are more likely to be aware of how students are and where the students are in terms of the research process than any other faculty members.

2.5.4. Postdoctoral supervisors as mentors

Mentors in postdoctoral training settings provide parallel academic mentoring functions in many ways. The role of postdoctoral supervisors may differ from that of PhD advisors because postdoctoral trainees are PhD recipients who are already trained to conduct research as independent scholars. However, differences in the expected roles of PhD advisors and postdoctoral supervisors overall may become negligible when their influences are focused on employment outcomes. In other words, the most prominent mentoring resources that postdoctoral supervisors provide to their postdoctoral trainees are the career-related instrumental resources contributing to the development of junior scholars' research productivity as well as insights and advice on job searches. Moreover, Johnson (2014) argues that the term supervision just replaces advising in postdoctoral training settings as discussions about the role of PhD advisors and postdoctoral supervisors remain relevant. As for research productivity, postdoctoral supervisors provide support to junior scholars to enhance graduate and postdoctoral outcomes (i.e., higher productivity) (Sinclair, 2004; Platow, 2012), which is an important recruitment criterion in academia. Regarding job searches and negotiations, postdoctoral supervisors help junior scholars make informed decisions when searching for and selecting jobs. Also, postdoctoral supervisors can advise candidates whether a position fits the candidates (Wei et al., 2012) because they have more knowledge and information about the availability and quality of jobs compared with job candidates. Moreover, postdoctoral supervisors serve as referrals (Wei et al., 2012). By formally and informally introducing their postdoctoral trainees to potential research colleagues, postdoctoral supervisors help junior scientists build scholarly connections. Formal and informal interactions with other scholars may play a key role "in coordinating the supply and demand for postdoctoral scholars" (Wei et al., 2012, p. 61) in their job attainment.

Both theoretical and empirical research emphasizes that mentoring help and support have positive impacts on junior scientists' career advancement outcomes, including their initial job attainment in the academic system, by enhancing their research productivity, which in turn makes them more competitive candidates in the job market. The following section applies Social Capital Theory to further discuss the positive impacts of mentoring support and advice from Ph.D. advisors and postdoctoral supervisors.

2.5.5. Mentoring and Social Capital Theory

Social Capital Theory is used to account for positive impacts of mentoring support and advice from Ph.D. advisors and postdoctoral supervisors on junior scientists' career advancement outcome in academic STEM fields. Social capital is defined as resources embedded in a network structure through which individuals can access to and mobilize the resources (Coleman, 1990; Lin, 1999; Bourdieu, 1985). Bourdieu (1985) provides one of the formal definitions of social capital as “the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition” (p. 248). In other words, social capital is the “social-structural resource” (Coleman, 1990, p. 302) that is based on social obligations or connections (Bourdieu, 1985). Examples of social capital include a broad range of tangible and intangible resources including financial resources, instrumental information, emotional support, acknowledgment, and reputation (Burt, 2000; Coleman, 1988, 1990).

Along with individuals' social relationships and resources available through the relationships, the definition of social capital also encompasses positive outcomes stemming from the relationships and resources. Like other types of resources, social capital is used to maximize desired outcomes. In fact, returns to social capital are productive and beneficial as the social capital converts to individuals’ human and economic capital (Coleman, 1988; Lin, 1999), which may increase the likelihood of success (Lin, 2001). Forret & Dougherty’s (2004) research findings support that social capital is associated with getting a better job, early promotion, and higher compensation. Campbell, Marsden, & Hurlbert (1986) also found that social capital and the occupational prestige are positively related. Other studies present empirical findings that social capital results in higher productivity (Brass & Krackhardt, 1999; Nahapiet & Ghoshal, 1998), getting a job faster (Sprengers, Tazelaar, & Flap, 1988), getting paid more (Burt, 1992), and being promoted more rapidly (Burt, 1992).

To reiterate, the definition of social capital integrates individuals' social relationships, tangible and non-tangible resources through the relationships, and positive outcomes stemming from the relational resources. It is well aligned with the concept of mentoring incorporating the components of interpersonal connection, providing support and advice through the connection, and career advancement outcomes. Linking the concept of mentoring and social capital theory is supported by previous studies identifying a causal influence between the two concepts in the model of career success (Wanberg et al, 2003; Kirchmeyer, 2005; Hezlett & Gibson, 2007) including greater career satisfaction, higher salaries, and more promotions (Ragins et al., 2000; Allen et al., 2004; Wanberg et al, 2003; Hezlett & Gibson, 2005; Noe, Greenberger, & Wang, 2002). In particular, Wanberg et al. (2003) & Kirchmeyer (2005) explain how mentoring resources improve mentees' career advancement outcomes by pointing out that mentees' performance outcome as the mechanism that links mentoring and career advancement outcomes. The receipt of the instrumental mentoring resource including research funding or facilities, and feedback about research, teaching, and services, improves mentees' proximal performance outcomes, which leads to more distal career advancement outcomes (Wanberg et al., 2003). In addition to the performance outcome, mentees' reputation and visibility in the field, which heavily relies on their mentors, also serves as a link between mentoring and mentees' career advancement outcomes (Durley, 2006). Through their professional network connections, mentors may introduce mentees to other scientists and increase the chance and opportunity to collaborate with them that otherwise would not be accessible to the mentees. Also, especially in the context of job applications, junior scientists' visibility in the hiring process may rely on mentors' reputation via recommendation letters. In fact, Nolan, Buckner, Marzabadi, & Kuck's (2008) findings demonstrate that, when it comes to the initial job placement, the effects of a mentor's reputation in the field is a more significant factor that determines junior scholar's career advancement outcome than their own research productivity outcome.

In summary, PhD advisors and postdoctoral supervisors provide instrumental and psychosocial mentoring resources to junior scientists. From the social capital perspective, such mentoring resources improve junior scientists' career advancement outcomes through their effects on proximal performance outcomes. The social capital theory also explains mentoring effects in a way that mentors' reputations and network connections have influences on mentees' job attainment because PhD advisors and postdoctoral supervisors serve as referrals.

In the following section, the focus of the discussion will shift to gender differences in mentoring resources. Together with career advancement outcome, studies of gender difference and bias have explored female scientists' disadvantages in social capital. Status Characteristics Theory (SCT) will again be applied to explain the gender difference in the mentoring resource.

2.6. Gender differences in mentoring in academic STEM: *Mentoring and Status Characteristics Theory*

Incorporation of gender, social capital, and mentoring provides insights for understanding integrated gender effects on mentoring resources, which together affect junior scientists' early stage career progress. In other words, it can address the question of to what extent, if any, female junior scientists face disadvantages in receiving mentoring help and advice.

The topic of gender and mentoring resources can gain insight from discussions of inequality in social capital. Social capital studies support the general understanding of gender inequality in obtaining social capital in academia (Etzkowitz, Kemelgor, & Uzzi, 2000; Xu & Martin, 2011; Bickel, 2014). In the context of non-mentoring professional networks, a key principle that explains disadvantages for female academic scholars is network structure. Female faculty have been provided unequal opportunities to enter and be included in a network, meaning lack of opportunities to access to social capital (Ibarra, 1992; Lin, 2000) due to an unwelcoming environment (Etzkowitz et al., 2000; Xu & Martin, 2011) as well as gender-biased performance expectations and evaluation. Instead of lacking opportunities to enter and be included in professional networks, gender differences in obtaining social capital in one-on-one relationships can be explained by having unequal opportunities to receive mentoring resources in quantity and kind due to the gender-biased performance expectations and evaluation.

It is important to note that Status Characteristics Theory (SCT) explains female scientists' disadvantages in career advancement outcomes. Recall SCT's key principle that accounts for female scientists' disadvantages in career advancement outcomes is gender-biased evaluation associated with gender stereotypes. In academic science, worker attributes, represented as highly valued worker qualities in academic science, are less likely to be associated with the female gender. Female scientists are perceived to be less fit as compared to their male colleagues in academic STEM, which in turn causes gender-biased performance expectations and evaluations.

Studies provide empirical evidence of gender-biased mentoring help and advice provision (Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012; White, 1970). White (1970) found that senior male scientists more readily identified male junior scientists over female scientists as their supervisees and successors. In experiments of hiring laboratory managers, Moss-Racusin et al. (2012) found that both male and female faculty members were more likely to hire and mentor male students. Both studies point out that the reason for the gender-biased mentoring opportunities is gender-biased performance expectation and evaluations; faculty members tend to perceive male students more competent than the identical female students.

Taking together the discussions of gender-biased performance expectation and evaluation as well as inequality in receiving mentoring resource, Figure 1 illustrates relationships between gender effects, mentoring resources, and the career advancement outcomes of junior academic STEM scientists.

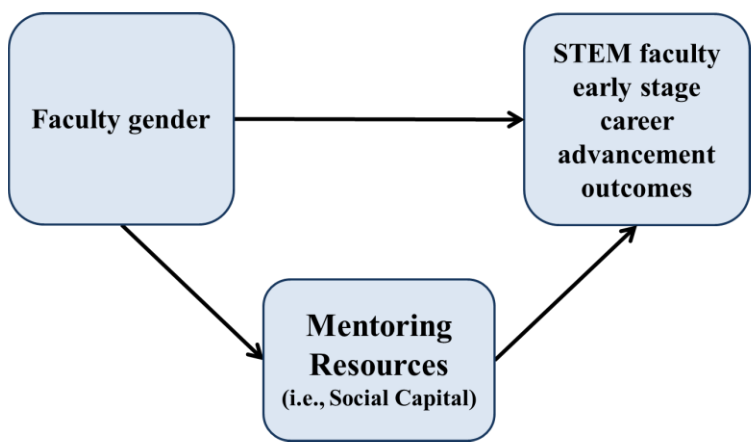

Figure 1. Proposed Conceptual Framework Illustrating Relationships between Gender, Mentoring Resource, and Early Stage Career Advancement Outcome among STEM Faculty

2.7. Summary: *Mentoring and Social Capital*

This section notes that mentoring relationships are the critical pathways for junior scientists to receive help and resources that improve their career advancement outcomes. It is also reviewed that PhD advisors and postdoctoral supervisors serve as mentors who provide the help and resources. In general, mentoring resource provision from PhD advisors and postdoctoral supervisors enhance junior scientists' scholarly performance, which in turn improves their career advancement outcomes. Mentors' scholarly reputations and their network connections to other experienced scholars in the field also affect mentees' performance as well as career advancement outcomes because mentees' reputations rely on that of their mentors. Additionally, mentoring resource provisions are gender-biased when incorporating Status Characteristics Theory and Social Capital Theory.

However, relying solely on gender bias in the receipt of mentoring resource reveals limitations in explaining the relationships between PhD students and advisors or postdoctoral scholars and their supervisors. For example, mentoring and social capital theory cannot fully explain whether gender composition in junior scientists' mentoring relationships with PhD advisorship and supervisorship impacts the extent of mentoring resource provision, or how the same-gender mentorships occur.

Creation of a mentoring relationship is determined by a combination of multiple factors including the resource availability, psycho-social factors derived from role model, similarity-attraction, and stereotype (Main, 2011; Zhao et al., 2007), and other individual and institutional factors such as shared research interest from both parties and availability of the faculty member to serve as a supervisor (Zhao et al., 2007). Moreover, mentor-mentee dyads require mutual agreements of both the junior person and senior member of academic science rather than being driven by either party (Joy et al., 2015). In the next section of this research, it will be discussed how mentor-mentee relationships in academic science occur by psycho-social factors. In particular, it will focus on how the matching occurs by the similarity-attraction so that the same-gender supervisee-supervisor relationships are formed. To explain the similarity-attraction in the creation of same-gender mentoring relationships and mentoring resource provision in such relationships, Ingroup Bias Theory will be used.

2.8. Ingroup Bias Theory: Gender homophily in PhD advisor-advisee and postdoctoral supervisor-supervisee dyads in academic STEM

In this section, Ingroup Bias Theory (IBT) is used to explain gender homophily in mentoring dyads and mentoring resource provision in the same-gender mentoring dyads within academic STEM fields.

IBT argues that individuals intuitively feel close to those who are similar to them (i.e., the ingroup). Closeness and fondness lead to favorable evaluations and treatments towards ingroup members than outgroup members (Brewer, 1979, 1999, 2007; Hewstone et al., 2002) as well as tune their attitudes and behaviors in favor of ingroup members (Brewer, 2007; Tajfel & Turner, 1986). The preferential treatments to ingroup members lead to benefits (Brewer, 1979, 1999, 2007; Hewstone et al., 2002) that range from protecting or enhancing positive social cognition, via political power (Tajfel & Turner, 1979), to providing more resource and help (Chen & Li, 2009) and giving less punishment (Mussweiler & Ockenfels, 2013). IBT also argues that the biases in favor of the ingroup over outgroups are the product of the intergroup competition over resources that are essential for the existence and success of the group (Brewer, 1979).

2.8.1. Creation of same-gender mentoring dyads and mentoring resource provision in the same-gender mentoring dyads

IBT's preferential treatment to ingroup members accounts for the creation of same-gender mentoring dyads and mentoring resource provision in the same-gender mentoring dyads in academic STEM fields. For female mentees, selecting female advisors may be in step with seeking a faculty member as their advisor who is similar to them, and envisioning potential career paths based on the experiences and successes of the female faculty member as a role model (Main, 2011). From the female mentor's perspective, they prefer to have female mentees due to same gender group identity, which leads to having the subsequent desire to help and promote female junior scholars as they provide more generous mentoring resources (Main, 2011).

IBT provides a better understanding of mentoring resource provision in the female-female mentoring dyads when it is integrated with the Status Characteristics Theory. One of the prominent motivations for individuals to perceive and treat ingroup members favorably is to elevate the status of the ingroup, which is ultimately to enhance self-esteem (Tajfel & Turner, 1979; Cameron & Lalonde, 2001). The tendency becomes stronger if the ingroup has negative group identity such as being discriminated and being regarded as the inferior group in the intergroup hierarchy (Tajfel & Turner, 1979; Cameron & Lalonde, 2001). In the Status Characteristics Theory section, it is argued that female scientists are viewed as less fit or as having inferior status in academic STEM based on gender-biased performance evaluations that are shaped by gender stereotypes. Thus, female scientists would tend to prefer other female mentors and mentees as they would provide favored treatment to improve group identities and elevate the overall status of female academic scientists in STEM fields.

Certainly, not all same-gender mentoring dyads between female scientists are outcomes of ingroup bias. For example, a female junior scientist may choose a female advisor because she values her advisor's scholarly reputation, intellectual compatibility, good personality, and willingness to help advisees graduate or get a job promptly (Joy et al., 2015; Zhao et al., 2007). Female-female advisorship can also occur based on non-gender-related similarity attractions such as race and ethnicity. However, same-gender mentoring dyads between female academic scientists as an outcome of ingroup bias are evident if the proportion of female junior scholars with female PhD advisors or postdoctoral supervisors is much higher than the average. Evidence, in fact, supports the assertion that female-female dyads are an outcome of ingroup bias by showing that female-female dyads are more likely to occur than male-male dyads in consideration of gender proportion in the field (Smeby, 2000).

Ingroup Bias Theory also explains the mentoring resource provision in the male-male mentoring dyads. Male senior scientists are more generous to male junior scientists by providing more psychosocial supports such as bestowing more responsibility and giving more feedback to junior male scientists to strengthen their personal identity as competent professionals (White, 1970; Moss-Racusin et al., 2012). However, the creation of same-gender mentoring relationships between male STEM scientists may not be impressive in the context of ingroup bias because they are a majority group. Most academic faculty positions are held by male faculty such that the majority of PhD students and graduates have male dissertation advisors or postdoctoral supervisors. Male PhD students and graduates thus typically experience same-gender advisor-advisee dyads, and female ones experience cross-gender dyads. Moreover, studies present another reason that IBT may not be very relevant to explain same-gender mentoring dyads between male scientists. Even though IBT studies note that higher status group is more likely to show ingroup bias, it is so if the status differentials are perceived to be legitimate (Bettencourt & Bartholomew, 1998; Hewstone et al., 2002). Academic science has long been a male-dominant and male scientists have been viewed as more suitable for academic science in terms of performance and productivity or of higher status in the field as compared to female scientists due to gender stereotypes (Castilla, 2008; Castilla & Bernard, 2010; Correll & Bernard, 2006; Correll et al., 2007; Ridgeway, 2011; Turco, 2010). However, such status characteristic and gender difference in academic science can hardly be viewed appropriate or reasonable. Thus, this study asserts that Ingroup Bias Theory is more applicable to account for the creation of same-gender mentoring dyads and mentoring resource provision in the same-gender mentoring dyads between female scientists in academic STEM fields as compared to male-male mentoring dyads.

2.9. Chapter summary and conceptual model

This chapter provides a basis for the core perspective of this study regarding gender, gender homophily in mentoring dyads, mentoring resource provision in the same-gender mentoring dyads in determining the early career advancement outcome for female scientists in STEM. Based on the components from the theories, Figure 2 summarizes and illustrates the conceptual model indicating direct and indirect impacts of gender, gender homophily, mentoring resource provision, and the career advancement outcome. First, female gender as a status characteristic has direct negative impacts on the career advancement outcome where female junior academic scientists have the longer time to advance to the next stage on their career path because of the gender stereotypes that make gender as a status characteristic. Second, mentoring resources provided by PhD advisors and postdoctoral supervisors contribute to junior scientists' successful degree completion, improved research skills, and productivity, which has positive impacts on their career advancement. Additionally, because of the gender as status characteristics that play a role as a barrier for female junior scientists to receive mentoring, the conceptual model indicates a relationship between gender and the mentoring resource, which also results in them having female junior scientists take the longer time to move to the next step in their career path. Lastly, gender homophily in mentoring dyads, as an outcome of ingroup bias, will lead to more mentoring resource for female junior STEM scientists, which ultimately results in positive impacts on their career advancement.

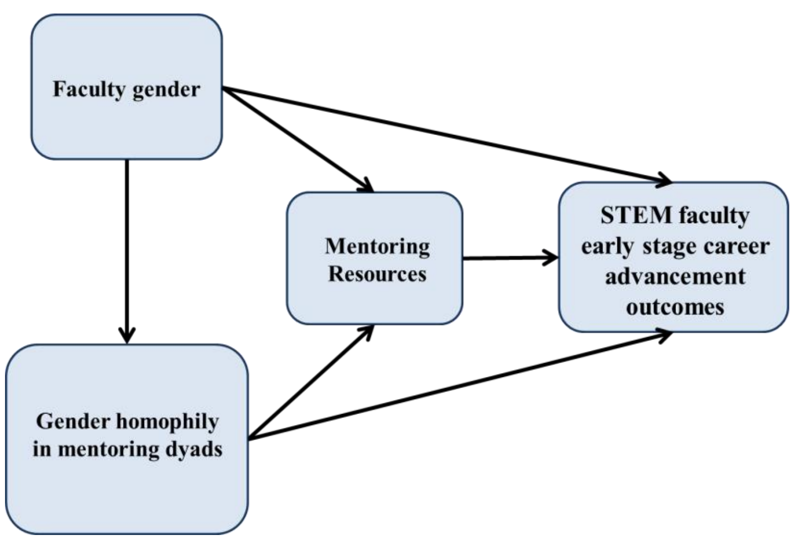

Figure 2. Proposed Conceptual Framework Illustrating Relationships between Gender, Gender Homophily in Mentoring Dyads, Mentoring Resource Provision in the Same-gender Mentoring Dyads, and the Early Career Advancement Outcome among STEM Faculty

3. Hypotheses

3.1. Introduction

The previous chapter established the context for understanding the role of gender, PhD advisors' and postdoctoral supervisors' mentoring help and advice, and gender homophily in mentoring dyads in determining junior scientists' career progress in academic science. Status Characteristics Theory, the concept of Mentoring and Social Capital Theory, and Ingroup Bias Theory provide insights to create the theoretical framework and to examine junior STEM scientists' career advancement in academic STEM field.

The theoretical frameworks also provide insights of combined effects of gender, mentoring, and gender homophily in mentoring dyads on junior scientists' career progress. For example, junior scientists' gender can influence the extent of receiving mentoring help and advice, which in turn influences junior STEM scientists' career progress. Also, gender homophily in mentoring dyads may have indirect impacts on junior scientists' career advancement outcomes through its effects on receiving mentoring help and advice.

In this chapter, junior scientists' gender, mentoring help and advice, and gender homophily in mentoring dyads are used as building blocks to develop integrated hypotheses to test direct and indirect influences on STEM scientists' early stage career advancement outcome. After presenting the hypotheses, an empirical model is presented that will be tested in the subsequent chapters.

3.2. Hypothesizing gender effects on academic STEM scientists' early stage career advancement outcome (H1)

Gender inequality in career advancement outcome, especially in the early career stage, in academic science has received empirical support. Studies have found that female academic scientists have disadvantages in obtaining permanent and secure faculty positions in academia (Ginther & Kahn, 2006; Nelson & Rogers, 2005; NRC, 2010; Wolfinger, Mason, & Goulden, 2008). NRC (2010) presents data showing the evidence of gender differences in faculty hiring in a slightly broader perspective. While other studies explore gender gap in the probability of being hired, NRC's (2010) report presents the percentage of male and female scientists who received the first job offer as well as the gender of candidates who eventually accepted each tenure-track position. In 95% of the cases in which a male candidate is the first choice for a position, a male candidate (whether the candidate is the one who received the first offer) is ultimately hired in that position. On the other hand, as compared to female scientists', the percentage decreases to 70%, which means that 30% of the cases in which female scientists are offered the position first, male ones eventually get the position (NRC, 2010). Wolfinger et al. (2008) show that female PhDs in STEM have significant disadvantages at the transitions into a tenure-track position as compared to non-STEM fields. Controlling for disciplines, Wolfinger et al. (2008) demonstrate that female PhD recipients in the STEM fields are less likely to obtain tenure-track academic positions than in the social sciences and humanities.

Female junior scientists' lower probability of getting a tenure-track faculty position can support the expectation of female junior scientists' delays in career advancement outcome. That female scientists' lower probability to get a job, as compared to their male counterparts, means that they are more likely to leave academia, settle for non-tenure-track positions, or temporarily take such positions until they get tenure-track positions. Ginther & Kahn's (2006) findings show partial support that it takes longer for female scientists to get a job. Ginther & Kahn (2006) reveal that there are significant gender differences in the likelihood of obtaining tenure-track jobs within five years of PhD receipt in science and engineering fields. Female scientists are 3.8% less likely to get tenure-track jobs within five years of PhD receipt than male scientists before controlling covariates such as PhD cohort, race, origin, PhD quality tier, and field (Ginther & Kahn, 2006). After controlling for such covariates, the gender difference remains significant; female scientists are 3.3% less likely to be hired (Ginther & Kahn, 2006). Their study does not measure the duration of time between receiving PhD and getting the first tenure-track position. However, their findings that female scientists are less likely to get a permanent job within five years of receiving PhD may be robust enough to support the delay of female scientists' career advancement for several reasons.

First, five years from receiving a PhD is a reasonable timeframe for academic scientists who pursue academic careers to obtain a permanent tenure-track job. Several studies exploring academic scientists' early stage career experiences use the five-year timeframe as an indicator of delay in academic placements (Nerad & Cerny, 1999; Su, 2013, NSB, 2012; NSB, 2016). Within the time duration, PhD recipients can complete several postdoctoral trainings or have non-tenure-track positions. Nerad & Cerny (1999) confirms that postdoctoral scholars are more likely to secure academic placements if their postdoctoral training lasts less than five years. The second reason that Ginther & Kahn's

(2006) findings can support the delay of female scientists' career advancement is that, in their research model estimation, they only include those who are more likely to pursue the academic career such that they stay in the job market until they obtain tenure-track positions. In particular, Ginther & Kahn (2006) only include those who held postdoctoral positions, any academic appointments, and had no job immediately after PhDs in their sample. By doing so, they could peer into the career advancement outcome among those who were likely to remain in the job market and seek academic jobs as excluding those who leave the academy. Thus, Ginther & Kahn's (2006) findings that female scientists are less likely to get tenure-track jobs within five years of PhD receipt than their male counterparts imply that more female scientists would remain in the job market longer than males.

Taken together the current findings and discussions, it is reasonable to expect gender difference in career advancement outcome in academic STEM fields, especially in the early career phase. Thus, I propose the following hypothesis.

H1. Female junior scientists, as compared to male scientists, will report slower early stage career advancement.

3.3. Hypothesizing mentoring resource effects on academic STEM scientists' early stage career advancement outcome (H2)

As discussed in the literature review section, mentoring help and advice are shown to benefit junior academic scholars regarding their career advancement outcomes. A goal for junior academic scholars is to obtain a secure job and to successfully make progress in their careers. Previous research has demonstrated that mentoring resource provision is closely associated with mentees' academic and career advancement outcomes by developing mentees' research productivity, skill, self-efficacy (Johnson, 2007; Gottschall, 2014). Studies demonstrate that mentoring relationships contribute to junior scholars' satisfaction with, and commitment to, their academic programs (Phinney, Campos, Kallemeyn, & Kim, 2011) as well as professional socialization, self-efficacy, interest in science and practice (Schlosser & Gelso, 2001; Schlosser & Kahn, 2007). Others also present mentoring effects on improving pre-doctoral and post-doctoral publications and presentations (Stroude, Bellier-Teichmann, Cantero, Dasoki, Kaeser, Ronca, & Morin, 2015; Clark, Harden, & Johnson, 2000; Hollingsworth & Fassinger, 2002) and time to complete PhD degrees and persistence (Barnes, 2010; Faghihi, 1998; Girves & Wemmerus, 1998; Lovitts, 2001; Nettles & Millett, 2006; Stroude et al., 2015).

From the social capital perspective, mentoring can enhance junior scholars' career advancement outcome via mentor's network connections. To reiterate, the well-connected network is an indicator of the high level of social capital. If a job candidate has a mentor who has ample connections in the field, the mentor's connections can help the candidate to get hired by increasing the probability that the mentor personally knows search committees in the hiring departments or universities (Lutter & Schröder, 2014). Being mentored by a well-cited and well-connected mentor is actually found to be a strong predictor of postdoctoral employment (Cameron & Blackburn, 1981; Sanders & Wong, 1985). Based on the discussions and findings, this study presents the following hypothesis about mentoring resource effects on STEM scientists' early stage career advancement outcome.

H2-1. PhD advisors' mentoring resource provision is positively associated with junior scientists' early stage career advancement.

H2-2. Postdoctoral supervisors' mentoring resource provision is positively associated with junior scientists' early stage career advancement.

3.4. Hypothesizing gender effects on mentoring resource from PhD advisors and postdoctoral supervisors (H3)

Studies have reported that female scientists receive less mentoring resources than their male counterparts. A primary concern regarding gender difference in mentoring resource is that female junior scientists lack mentoring opportunities (Correll & Benard, 2006; White, 1970; Moss-Racusin et al., 2012) as well as the quantity (Van Emmerik, 2006) and quality of mentoring help and advice (Dutt et al., 2016; Sheltzer & Smith, 2014). Moss-Racusin et al. (2012) found the provision of mentoring is gender biased. In experiments on hiring laboratory managers, they found that both male and female faculty members favor male over female applicants based on perceptions of competence, hireability, and willingness to mentor (Moss-Racusin et al., 2012). In line with the lack of mentoring opportunity, female academic scholars receive less mentoring resources including provision of advice, contacts, coaching, and assistance with challenging assignments than male counterparts (Van Emmerik, 2006).

Other studies also found that female junior scientists lack mentoring resources in terms of the quality of mentoring help and advice (Dutt et al., 2016; Sheltzer & Smith, 2014). Sheltzer & Smith (2014) examine the gender distribution of trainees in laboratory settings, and they found a significant gender difference in the number of trainees in the laboratory run by professors with the higher reputation in the field. There is 41 to 42% female graduate students who are hired as research assistants in laboratories that are run by male professors with the higher reputation (i.e., prestigious scholarly society members and major award winners), while there is 47 to 48% female graduate students hired in other laboratories run by other male professors (Sheltzer & Smith, 2014). This gender gap represents a 14% to 17% dearth in the female graduate students' employment in award-winning laboratories, relative to their representation across all laboratories. Sheltzer & Smith (2014) also show the significant gender skew in the laboratories among postdoctoral scholars. Male postdoctoral scholars are about 25% more likely to do their postdoctoral training with award-winning PIs (Sheltzer & Smith, 2014). Furthermore, male trainees are 90% more likely to do their postdoctoral training with Nobel Laureates (Sheltzer & Smith, 2014). Dutt et al. (2016) present additional evidence that shows female graduate students' disadvantages in receiving mentoring regarding quality. In a review of words and phrases used in recommendation letters, they found that male students receive stronger recommendation letters from their PhD advisors. It may have critical adverse outcomes for female junior scientists' career progress if they are less likely to receive a strong recommendation letter or have fewer opportunities to be hired in laboratories. The recommendation letter is one of the critical resources that PhD advisors give to their students, which provides the candidate's first impression of candidates to search committees and the hiring departments (Dutt et al., 2016). Also, work as a lab manager is helpful for STEM graduate students to enhance their research experiences as well as to exercise their leadership.

Given that the existing findings and discussions, it would be logical to expect a gender difference in mentoring resource provision from PhD advisors and postdoctoral supervisors in academic STEM fields.

H3-1. Female junior scientists, as compared to male scientists, will report fewer mentoring resources received from PhD advisors.

H3-2. Female junior scientists, as compared to male scientists, will report fewer mentoring resources received from postdoctoral supervisors.

3.5. Hypothesizing gender effects on gender homophily in PhD advisor-advisee and postdoctoral supervisor-supervisee relationships (H4)

As discussed in the literature review section, gender homophily in mentoring relationships is proposed based on Ingroup Bias Theory that argues that people tend to be drawn to, and positively treat, those who are similar to themselves regarding demographic characteristics, behaviors, and attitudes (O'Neill & Blake-Beard, 2002; Turban & Jones, 1988). Existing studies report that there is strong ingroup bias in mentoring and supervisory relationships. Smeby (2000) found a significant same-gender tendency in graduate supervisory relationships from the mentors' perspectives. Both female and male academic faculty members from humanities, social science and natural science fields in Norwegian universities reported significant same-gender graduate supervisory relationships (Smeby, 2000). Blake-Beard et al. (2011) also report significant tendency in generating same-gender mentoring relationship in the academic STEM.

The same-gender tendency in generating mentoring relationship appears to be stronger among females. Blackburn et al. (1981), Feeney (2006), and Smeby (2000) found that the same-gender tendency in mentoring relationships is stronger among females in both academic and non-academic settings. Feeney (2006) found that female mentees are significantly more likely to report having female mentors among public managers. Blackburn et al. (1981) demonstrate that female academic mentors listed twice as many mentees as their male mentors, and Smeby (2000) found that female faculty members supervise 1.8 male students and 3.6 female, while male faculty members reported that they supervised on average 3.4 male graduate students and 2.7 female students.

There is at least one study showing contradictory findings that supports stronger same-gender tendency in mentoring relationships among male. Blake-Beard, Bayne, Crosby, & Muller (2011) show that a greater proportion of male junior scientists in STEM fields (including undergraduate and graduate students and postdoctoral scholars) indicated that they had same-gender mentorship; 71% of females reported that they have female mentors whereas 87% of males did. However, it may not be that female junior scientists are less likely to have female mentors or find gender matching mentoring less important. Rather, it is because of the lower representation of female scientists on both senior-level and junior-level in the field. In fact, female junior STEM scientists are "more likely to say it was important to have a mentor who understands how their background effects their experiences as a student in their field than were [males]" (Blake-Beard et al., 2011, p. 633). Other studies also indicate that female value same-gender mentorship. Gilbert's (1985) findings show that female graduate students are more likely to view the same-gender mentoring relationships as essential to their professional development. Female mentees describe their female mentors as “successful, aggressive, competent, and highly motivated” (Heinrich, 1995, p. 453). Based on the previous discussion, the following sets of hypotheses about gender differences in same-gender mentoring dyads are proposed.

H4-1. Female junior scientists will be more likely to have a same-gender PhD advisor as compared to male scientists.

H4-2. Female junior scientists will be more likely to have a same-gender postdoctoral supervisor as compared to male scientists.

3.6. Hypothesizing indirect gender effects on academic STEM scientists’ early stage career advancement outcome through gender homophily in PhD advisor-advisee and postdoctoral supervisor-supervisee relationships (H5)

Previous sections posit a direct relationship between junior scientists’ female gender and mentoring resource from PhD advisors and postdoctoral supervisors (H3) and gender homophily in mentoring dyads (H4). In this section, an indirect effects of junior scientists’ gender on mentoring resource provision from PhD advisors and postdoctoral supervisors through the same-gender mentoring dyads is posited.

There is lack of consensus in the empirical evidence on the beneficial effects of gender homophily in mentorship in the reception of more instrumental mentoring resources for women. For example, Goldstein (1979) found that junior female psychologists who had female mentors in the doctoral program reported higher postdoctoral scholarly productivity than those who had been supervised by male mentors. Some other studies reveal that female academic scholars receive more professional development support from female mentors (Blake-Beard et al., 2011). In comparison, other research has demonstrated that there is no empirical support for the question whether female mentees receive either less or more mentoring resource through the same-gender mentoring dyads (Over, Over, Meuwissen, & Lancaster, 1990; Ragins, 1999; Turban, Dougherty, & Lee, 2002; Schlosser et al., 2011).

On the other hand, there are more empirical studies that have demonstrated that female mentees receive more psychosocial mentoring resources through the same-gender mentoring dyads than male mentees receive resource through male-male dyads. Studies show that female students and workers who have female mentors experience greater psychosocial support (Allen & Eby, 2004; Blake-Beard et al., 2011; Ensher & Murphy, 1997; Schroeder & Mynatt, 1999) including acceptance, friendship, and advice (Allen, Day, & Lentz, 2005). It is also demonstrated that female mentees find more persuasive and useful role models of the professional manner and career development from female mentors (Richey, Gambrill, & Blythe, 1988; Sosik & Godshalk, 2000). For example, Sosik & Godshalk (2000) show that mentees in female-female mentoring relationship rate their mentors significantly higher than those who are in male-male relationships. Female graduate students, unlike male students, rate the role model relationship as important as their professional development (Gilbert, 1985). Studies also found beneficial role modeling effects of same-gender mentoring dyads from the mentors' perspective. Burke, McKeen, & McKenna (1990) show that female mentors reported providing more friendship, counseling, and personal support in same-gender mentoring relationships than any other gender composition. Positive role model mentoring functions in same-gender mentorship can also be emphasized by Ragins and McFarlin's (1990) finding that mentees' in cross-gender dyads reported lower role modeling functions received than mentees' in same-gender mentoring dyads. Moreover, Ragins (1997) concluded that "the degree of diversity in the mentoring relationship should be inversely correlated with the provision of psychosocial and role modeling functions" (p. 503).

Indeed, studies argue and show that psychosocial mentoring function is particularly important for women (Shakeshaft, 1987; Gilbert, 1985; Cullen & Luna, 1993), especially for those who are in the field where female workers are traditionally scant (Chesler, Boyle Single, & Mikic, 2003). For both female and male mentees, perceived similarity and interpersonal comfort in same-gender mentoring dyads may increase the frequency of interactions with their mentors, which can improve their mentorship experiences. Additionally, same-gender mentoring relationships can provide opportunities to discuss feelings of isolation, work-life balance, educational climate, performance expectation, and how the senior female professionals have broken down gender barriers throughout their career (Chesler, Boyle Single, & Mikic, 2003; Brainard & Ailes-Sengers, 1994; Brainard & Carlin, 1998; Clewell & Campbell, 2002). After going by all the discussions above, the following set of hypotheses are proposed.

H5-1: Female scientists with same-gender PhD advisors will report greater mentoring resources than male scientists with same-gender PhD advisors.

H5-2: Female scientists with same-gender postdoctoral supervisor will report greater mentoring resources than male scientists with same-gender postdoctoral supervisor.

3.7. Hypothesizing indirect gender homophily in PhD advisor-advisee and postdoctoral supervisor-supervisee relationships on academic STEM scientists' early stage career advancement outcome through mentoring resource from PhD advisors and postdoctoral supervisors (H6)

This section presents the last set of hypotheses testing indirect effects of gender homophily in mentoring dyads on academic STEM scientists' early stage career advancement outcome through mentoring resource provision. The indirect relationship is expected to capture the overarching effects of mentoring resource provision and gender homophily on academic STEM scientists' early stage career advancement outcome.

As discussed above, it is expected that there will be positive indirect effects of junior scientists' gender on mentoring resource provision from PhD advisors and postdoctoral supervisors through the same-gender mentoring dyads. Similarly, the relationship between mentoring resource provision on academic STEM scientists' early stage career advancement outcome (H2) is also expected to be positive. Based on the two hypothesized relationships, this study posits that gender homophily in mentoring dyads will have the positive impact on academic STEM scientists' early stage career advancement outcome through mentoring resource provision.

H6-1: Female scientists who had the same-gender PhD advisors will report enhanced early stage career advancement through advisor mentoring resource provision compare to those who had the cross-gender PhD advisors.

H6-2: Female scientists who had the same-gender postdoctoral supervisors will report enhanced early stage career advancement through the supervisor mentoring resource provision compare to those who had the cross-gender postdoctoral supervisors.

3.8. Empirical model and chapter summary

This chapter developed specific hypotheses by integrating Status Characteristics Theory, the concept of mentoring, Social Capital Theory, and Ingroup Bias Theory to explain STEM faculty early stage career advancement outcome. Figure 3 represents the empirical model to test the hypotheses.

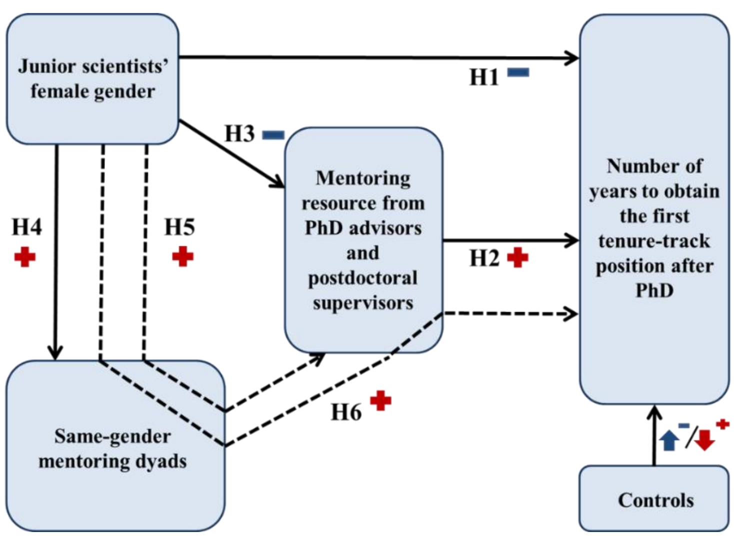

Figure 3. Empirical Model Illustrating Relationships between Gender, Mentoring Resource, Gender Homophily, and STEM Faculty Early Stage Career Advancement Outcome

Note: Dotted lines and arrows indicate indirect effects.

Status Characteristics Theory explains that female scientists have disadvantages in career advancement outcome due to the gender biased performance evaluation shaped by gender stereotypes (H1). The concept of mentoring together with social capital theory provides insights to propose Hypothesis 2. It expects positive mentoring resource effects on STEM faculty early stage career advancement outcome. The third hypothesis is presented using Status Characteristics Theory and the concept of mentoring. Hypothesis 3 expects that being female is negatively associated with receiving the mentoring resource from PhD advisors and postdoctoral supervisors.

Ingroup Bias Theory (IBT) assists with the development of several hypotheses. Based on one of the IBT's key ideas of similarity attraction, Hypotheses 4 and 5 test IBT's two ideas of the similarity-attraction in generating mentoring relationships and generosity in resource provision. Hypothesis 4 expects that both female and male junior scientists will report the same-gender mentoring dyads with PhD advisors and postdoctoral supervisors. Hypothesis 5 expects the indirect gender effects on mentoring resource provision through the same-gender mentoring dyads. Hypothesis 6 proposes the indirect positive effects of gender homophily in mentoring dyads on STEM faculty early stage career advancement outcome through mentoring resource effects.

The empirical model also has controls that represent factors that may impact STEM faculty early stage career advancement outcome. Firstly, junior scientists' research productivity is an important factor to consider in the context of academic career advancement. Secondly, certain STEM disciplines may have impacts on academic scientists' career advancement. For example, female junior scientists in STEM disciplines with the higher representation of female scientists such as bioscience may have enhanced career advancement compared to those who are in disciplines with lower female representation such as engineering. Female junior scientists may have a higher probability of having female mentors, which may be associated with the reception of more mentoring resource, thus improving career advancement outcomes.

4. Data, Measures, & Research Methods

4.1. Introduction

Based on the theoretical approaches of status characteristics, mentoring, and ingroup bias, the previous chapter presented a framework to examine junior STEM scientists' career advancement outcomes. In particular, the framework provided a foundation to establish hypotheses illustrating how gender, mentoring, and gender homophily in mentoring relationships, together, influence junior-level female scientists' career advancement in early career phase.

The goal of this chapter is to discuss the data and data analysis process to test the hypotheses to determine how gender (of junior STEM scholars as job applicants as well as the gender of PhD advisors and postdoctoral supervisors) and mentoring resources from PhD advisors and postdoctoral supervisors affect STEM faculty time to obtain the first tenure-track positions. Thus, in this chapter, data collection methods, variables used in the analysis, methods to handle missing data, and the data analysis procedures are discussed. The next section discusses the survey data including how the sample frame and final sample for the data analysis were created. The subsequent section describes how the dependent variable (i.e., junior STEM scientists' early stage career advancement after receiving PhD), key predictor variables (i.e., gender, mentoring resource provision from PhD advisors and postdoctoral supervisors), and control variables are operationalized and measured. The next section discusses extent and pattern of missing data as well as methods to handle it. Finally, this chapter concludes with an overview of the data analysis strategies.

4.2. Sample development and data collection process

This study uses data from a National Science Foundation (NSF) funded national survey of scientists and engineers from higher educational institutions in the United States[1]. The survey was completed in 2011, and it was designed to collect data on academic scientists' professional and demographic backgrounds, research productivity, teaching and professional activities, and network data. The sample frame included four STEM disciplines (i.e., Biology, Biochemistry, Civil Engineering, and Mathematics) based on the level of female representation (NSF, 2009). "Biology and Biochemistry are 'high' producers of women doctorates, Math is a 'transitioning (medium)' producer of women, and Civil Engineering is a 'low' producer of women" (NETWISE II codebook_v6, p. 25). The overall sampling strategies created the institutional sample in a way that the data represents STEM faculty in a broader institutional type (NETWISE II codebook). Thus, in the data set, STEM faculty members at various types of institutions including research intensive/extensive, master's, women's college, liberal arts colleges, Hispanic-serving institutions and historically black colleges and universities are captured (NETWISE II codebook).

The sample development started from manually collected information from faculty directories of science and engineering departments at universities' official website and faculty members' web pages. Types of information collected through the data collection process include: faculty members' race and ethnicity, gender, academic position and rank, department and university contact information, institution type, and

[1] Data comes from the following project funded from the following NSF Grant: "Breaking through the Reputational Ceiling: Professional Networks as a Determinant of Advancement, Mobility, and Career advancement outcomes for Women and Minorities in STEM" (NSF Grant # DRL-0910191).

STEM discipline. The final sampling frame contained 25,928 STEM faculty members representing various combinations of institutions, STEM discipline, gender, and race/ethnicity (NETWISE II codebook, v6). Snowball sampling approach was also implemented to identify and organize additional minority faculty members to be surveyed. Respondents in the original sample were asked to identify other STEM faculty members whom they know, and the same survey was sent to the snowball sample.

The survey was administered online using Sawtooth Software®. Participants were invited to the survey via personalized email with a series of personalized email follow-ups and one mailed reminder. The emails contained the URL of the survey website, individually assigned user ID, and password to complete the survey. The survey took 30 to 45 minutes to complete.

The survey contained questions asking respondents about their background, such as detailed demographic information, academic and professional backgrounds, productivity, research (e.g., grant submission and success rate)/teaching/service activities, publications, job experience and satisfaction, perceptions of the work and institutional environment. The survey also collected network data to discover respondents' relationships with other STEM scientists regarding network content and knowledge exchange (i.e., career development, collaborating in grants/teaching, getting advice). It is important to note that the network data collected in this survey is ego-centric, which means that the survey questions are about the relationships of the respondents (i.e., ego) rather than the whole network that the egos are members of (Wasserman & Faust, 1994). Respondents were asked to provide names of people whom they have connections with and describe their relationships regarding following activities: discussing teaching-related issues and departmental issues with, getting advice about career and professional development from, and collaborating with for research and teaching. Therefore, this survey captured the extent of the career development, collaborative, advice, and teaching networks that cannot be accessible through other data sets providing the ego-level data. After respondents had completed name generator questions, name interpreter questions were provided. The survey piped the alter's name into the name interpreter questions and asked respondents details about the alters including the type of the collaboration that the respondent undertook with the alter as a collaborator, origin of the relationship, level of relationship closeness, communication frequency, type of resource provision from the alter, and the alter's general demographics (NETWISE II codebook, v6). Alter-level data can be converted to ego-level data by aggregating the alter data to each respondent (NETWISE II codebook, v6). In addition to the ego-level and alter-level data, , bibliometric data was also collected to capture ego's publications over time. The bibliometric data is pulled down from Web of Science.

Among 4,313 completed and partially completed surveys, 4,196 were used for the final analysis. 117 were removed due to ineligible rank or discipline. The responses produced a total of 32,810 unique alters, or network members. The overall response rate for the survey was 40.4%, and the weighted response rate was 43.0%. The response rate was calculated using the Response Rate 2 as defined by the American Association for Public Opinion Research (AAPOR) (NETWISE II codebook, v6).

Table 1.

Overall Responses of the Survey Data

Number of complete responses	3,560

Number of partial or break-off with partial information	636
Number of explicit refusal	339
Number of nothing was ever returned	5,551
Number of unreachable respondents	295
Number of Selected respondents screened out of sample	116
Number of ineligible for sample	114

Table 1 provides the overall distribution of total number of survey respondents across several sample stratification categories: gender, position, STEM discipline, race/ethnicity, and institution type. Distribution of the respondents by gender is as follow; females comprised 43.2%. The survey focuses on the experiences of female scientists and engineers, so female scientists are oversampled to ensure that there are adequate numbers for gender-based comparison. Assistant professors take up 27.0%, associate professors take up 32.8%, and full professors take up 39.0%. As for STEM disciplines, Biology make up 36.5%, Biochemistry is 14.8%, Civil Engineering is 18.1%, and Mathematics makes up 23.1%. Distribution of the respondents by race/ethnicity is as follows: White (61.0%), African American (7.1%), Native American (0.4%), Asian (23.1%), Hispanic (5.6%), and Other/Unknown (2.8%). Survey also collected information about institution type that STEM faculty members work at. 45.7% of respondents work in research intensive/extensive universities, 13.0% work at liberal arts colleges, 4.4% is at women's colleges, 10.7% is at Hispanic-Serving institutions, 8.8% is at Historically Black Colleges and Universities, and 17.3% work at Master's institutions.

4.3. Description of Final Sample

Several criteria are used to get the final sample for this research context. The first criterion is either respondents are currently on the tenure-track positions (already tenured or not-yet-tenured but expect to be tenured soon), or they have had such positions before even though they currently have non-tenure-track positions. The second criterion is that respondents are either at the assistant, associate, or full professor rank. Respondents who reported that their current positions were ‘other’ are not included in the final sample.

The final sample size for this study is 3,968 academic STEM faculty. The overall distribution of the final sample used in this study is presented in Table 2. In the final sample, female STEM faculty comprises 42.8% (1,698 out of 3,968) of the sample. By rank, 26% (1,033 out of 3,968) are assistant, 33.5% (1,328) are associate, and 40.5% (1,607) are full professors. Distribution by STEM disciplines is as follows; 38.4% (1,381 out of 3,597) are in Biology, 16 % (576) are in Biochemistry, 19.8% (711) are in Civil Engineering, and 25.8% (929) are in Math. As for the institution type, 45.0% (1,784 out of 3,964) of the sample works at Research Intensive/Extensive universities. Distribution of the sample by PhD cohort based on the median PhD year (of 1995) is as follows; 46.4% (1,842 out of 3,968) reported that they received their PhD in ‘1995 and earlier’ and 53.6% reported their PhD year as ‘1996 and later.’ Due to missing data, the final sample in the analysis may be less than 3,968. Description of the missing data and handling strategies will be discussed later in this chapter.

Table 2.

Overall Distribution of Total Number of Survey Respondents and Final Sample

	Total number of survey respondents (N=4,196)	Final sample (N=3,968)
Women	43.2%	42.8%
Men	56.8%	57.2%
Assistant Professor	27.0%	26.0%
Associate Professor	32.8%	33.5%
Full Professor	39.0%	40.5%

Biology	36.5%	38.4%
Biochemistry	14.8%	16.0%
Civil Engineering	18.1%	19.8%
Mathematics	23.1%	25.8%
Other fields	7.6%	9.3%
White	61.0%	61.5%
Asian/Pacific Islander	23.1%	23.2%
African-American/Black	7.1%	7.1%
Hispanic	5.6%	5.5%
Native American/Alaskan Native	0.4%	0.4%
Other/Unknown	2.8%	2.3%
Research Intensive/Extensive	45.7%	45.0%
Liberal Arts Colleges	13.0%	13.4%
Women's Colleges	4.4%	4.6%
Hispanic Serving Institutions	10.7%	11.1%
Historically Black Colleges and Universities	8.8%	8.3%
Master's Institutions	17.3%	17.6%

4.4. Description of measures for variables

4.4.1. Dependent variable: ***Number of years to obtain the first tenure-track position after PhD***

The primary interest in the modeling section is to determine how gender, mentoring resource, gender homophily in the mentoring dyads affect STEM faculty early stage career advancement outcome. To measure academic STEM scientists' early stage career advancement outcome, this study uses the number of years to obtain the first tenure-track position after PhD as the dependent variable. The variable is calculated using two survey questions: (1) "In what year did you complete your PhD?" And (2) "In what year did you begin your first tenure-track position?" Respondents completed the two fill-in-the-blank questions as they provided the applicable information. Given that both variables have numerical data, the number of years to obtain the first tenure-track position after PhD is calculated by subtracting the year that respondents received PhD from the year that they obtained the first tenure-track positions.

For STEM faculty members in the final sample, the average time to obtain the first tenure-track position is 3.15 years. It ranges from -28 (i.e., obtained the first tenure-track positions 28 years before receiving PhD) to 42 years (i.e., got the first tenure-track positions 42 years after receiving PhD). 4.37% (166 out of 3,779[2]) respondents who reported that they obtained the first tenure-track positions before they received PhDs. 22.03% (837 out of 3,779) respondents reported that they obtain the first tenure-track position at the same year that they received PhD. As detecting and handling outliers, the 166 respondents who stated that they obtained first tenure-track position before receiving PhD were paid attention to.

Among those who reported that they obtained the first tenure-track position before receiving PhDs, more than half stated that they got the position a year or two years before their PhD. 48.19% (80 out of 166) reported a year (i.e., number of years to obtain the first tenure-track position of -1) and 9.64% (16 out of 166) reported two (i.e., number of years to obtain the first tenure-track position of -2). It is reasonable to include those whose number of years to obtain the first tenure-track position of -1 or -2 (82 respondents) is included in the final sample because it is quite common for STEM scientists to get academic faculty position while they are in PhD programs, especially in non-research intensive institutions. Some may have academic positions including postdoctoral training and non-tenure-track positions (Su, 2011, 2014) and others may have non-academic

[2] N does not add up to the final sample of 3,968 due to the missing cases. Among the final sample of 3,968, 3,799 respondents reported both the year of receiving PhDs and obtaining the first tenure-track position to calculate the number of years between the two events.

positions in industry and government. Although it is not very common, some academic scientists are tenured or in tenure-track positions without a PhD. Among the 70 respondents who reported that they obtained the first tenure-track position 3 to 28 years before they received PhD, most work at non-research intensive/extensive institutions such as master's, women's college, liberal arts colleges, Hispanic-serving institutions and historically black colleges and universities (77.14%) without having gone through postdoctoral training (91.43%). Their preferred career choices were non-tenure-track academic positions, academic positions at teaching intensive institutions, or positions in industry or government (81.43%). Thus, it is also reasonable to include them in the final sample because they may help account for factors influencing career advancement outcome for STEM scientists who get faculty positions right after they receive PhD. As a result, 3,799 respondents are included in the final sample. Table 3 shows the descriptive statistics of the number of years to obtain the first tenure-track position.

Table 3.

Summary Statistics of the Number of Years to Obtain the First Tenure-track Position

Variable	N	Mean	Std. Dev.	Min	Max
Number of years to obtain the first tenure-track position after PhD	3,799	3.15	4.08	-28	42

4.4.2. Independent variables: *Determinants of STEM scholars' time to obtain the first tenure-track position*

4.4.2.1. Gender and gender homophily

Gender of junior academic STEM scientists *(i.e., mentees' gender)* is a primary predictor variable in the research model for this dissertation. It is a dichotomous variable measured as "1" (Female) or "0" (Male).

Two variables indicating mentors' gender (i.e., PhD advisor and postdoctoral supervisor) are also coded one for female advisors or supervisors and zero for male advisors or supervisors[3]. Mentors' gender variables are generated to indicate effects of ***gender homophily in mentoring dyads*** in the model. Gender homophily in mentoring dyads effects will be analyzed in the model as a form of interactions terms by multiplying the two dummy coded variables of the gender of mentee (i.e., junior STEM faculty) and mentors. Gender homophily in the mentoring dyads is often studied in career progress of women in science in the context of its impact on female PhD students' likelihood of degree completion, time to complete the degree, the volume of publications, and job placement. Table 4 presents how the interaction terms indicating impacts of gender homophily in mentoring dyads.

[3] To obtain the gender variable of PhD advisors and postdoctoral supervisors, two sets of survey questions asking respondents were used: (i) who was their dissertation chair and the most recent postdoctoral supervisor and (ii) to fill out the name(s) of their dissertation chair and the most recent post-doc supervisor in the following name generating questions. Variables indicating the gender of PhD advisors and postdoctoral supervisors were created based on the names provided by junior STEM who completed the survey. As searching the names on the Internet, three sets of reference variables in the survey were used for crosscheck: (1) type of STEM discipline where the respondent is in, (2) PhD institution that the respondent graduated from, (3) two network resource variables (from network – alter data) indicating (3-1) whether the network resource is provided by PhD advisors or postdoc supervisors as well as (3-2) whether the resource provider is female or male.

Table 4.

Interaction Terms for Gender Homophily in Mentoring Dyads

		PhD advisors & postdoctoral supervisor (mentor)	
		Female mentor (=1)	Male mentor (=0)
Junior STEM faculty (mentee)	Female mentee (=1)	*Female mentor – female mentee*	Male mentor–female mentee
	Male mentee (=0)	Female mentor–male mentee	*Male mentor–male mentee*

Note: Italicized text indicates same-gender mentoring dyads

4.4.2.2. Mentoring resource for job searching: from PhD advisors

To operationalize and measure effects of different types of the mentoring resource from PhD advisors, multiple survey questions are used as observed variables to infer effects of each mentoring resource type. Confirmatory factor analysis (CFA) technique is used to determine whether observed variables significantly measure the mentoring resource effect. CFA test is conducted using MPlus software version 7.31.

Help from PhD advisor when applying for the first tenure-track job. Variables indicating PhD advisor's help when the job candidates apply for a certain position are also used because PhD advisors' recommendation letter, making phone calls to recruiters, or giving advice on negotiating can critically determine employment outcomes for PhD students (Barnes & Austin, 2009; Platow, 2012). The survey also asked respondents to indicate whether their PhD advisors had done the following during their first job search (1=done, 0=not done): (i) making phone calls for job search, (ii) writing recommendation letter(s), (iii) defending your career choices with colleagues, and (iv) giving advice about how to negotiate. The results of CFA test suggest that the four observed variables significantly contribute to measure the help from PhD advisors when applying for the first tenure-track job at the 0.001 level.

Advice from PhD advisor when seeking the first tenure-track job. Variables indicating PhD advisor's advice on job positions are included in the research model. With knowledge and information about the job market in general or certain universities and department, PhD advisors can advise their students whether the position fits the candidate (Wei et al., 2012). To measure the PhD advisors' help on job applications, the survey asked respondents whether their PhD advisors had advised them when the respondents had sought the following positions (1=advised, 0=not advised): (i) postdoctoral position, (ii) research-intensive position, (iii) teaching-intensive position, (iv) more competitive position than you were interested in, and (v) less competitive position than you were interested in. The results of CFA test also suggest that the five observed variables significantly contribute to measure the advice from PhD advisor when seeking the first tenure-track job at the 0.001 level.

4.4.2.3. Mentoring resource for research collaboration and career development: from PhD advisors and postdoctoral supervisors

In addition to PhD advisors' help and advice on job searches and applications, this study also examines whether junior STEM faculty's current relationships with their PhD advisors and postdoctoral supervisors have impacts on junior STEM faculty's time to get the first tenure-track positions. STEM faculty members' current relationship with their past PhD advisors and postdoctoral supervisors may be a reasonable proxy for their experiences of mentoring relationship at the time they were in the mentoring relationship according to Kram's (1983) four stages of mentorship. The stages include initiation, cultivation, separation, and redefinition (Kram, 1983). Faculty mentors and mentees would be ‘separated’ as PhD students or postdoctoral scholars finish their programs and get a job. Instead of terminating the relationships after the separation, mentors and mentees can ‘redefine’ and continue their scholarly relationships as converting it to the colleagueship (Kram, 1983). Therefore, that faculty members still have close relationships with their PhD advisors and postdoctoral supervisors may indicate that they also had close (even closer) relationships at the time the junior STEM faculty applied for their first job. In fact, the active research collaboration between students and PhD advisors increase the students’ future research productivity. Network connection variables indicating PhD advisors’ and postdoctoral supervisors’ help and advice on research collaboration and career development are included in considering the research context that is junior STEM faculty’s employment outcome.

To ensure the robustness of using variables representing junior STEM faculty’s current relationships with their PhD advisors and postdoctoral supervisors, additional models will be tested using the sample only comprised of respondents who are at the rank of assistant.

For each research collaboration and career development mentoring indicator, binary variables (1=yes, 0=no) indicating whether junior STEM scientists received PhD advisors’ and postdoctoral supervisors’ help and advice regarding research collaboration and career development are used. CFAs are also conducted and the results show that the observed variables significantly contribute to measure the index variables of mentoring resource for research collaboration and career development at the 0.001 level.

Research collaboration. The first set of non-job-searching mentoring resource indicators is junior scientists' research collaboration experiences with their PhD advisors and postdoctoral supervisors. Research collaboration variables are obtained by using network resource questions from the survey and the variables indicating PhD advisors and postdoctoral supervisors. By conducting CFAs, three survey questions about research collaboration experience are used to create a factor variable indicating junior scientsits' reseach collaboration experience with their PhD advisors: (i) research grant proposal, (ii) teaching or curricular grant proposal, and (iii) published one or more articles together. CFA results also conclude that the same three research collaboration variables significantly contribute to measure junior scientists' research collaboration experience with their most recent postdoctoral supervisors at the 0.001 level.

Help on career development. Two mentoring variables indicating help on career development from PhD advisors and postdoctoral supervisors are created by combining five survey questions asking respondents whether their PhD advisors and postdoctoral supervisors have (i) reviewed [their] papers or proposals prior to submission (on which they were not a co-author), (ii) introduced [them] to potential research collaborators, (iii) invited [them] to join a teaching or research grant proposal team, and (iv) recommended [them] as an invited speaker/panel member, and provided [them] with research or other funding. Each survey question is coded as 1 as yes and 0 as no. CFAs are conducted when combining the survey questions to analyze patterns of correlation between the questions and verifying that the grouped items have internal consistency. CFA yield significant results at the 0.001 threshold.

Seeking advice on research. PhD advisors' and postdoctoral supervisors' advice on research variable is created by combining survey questions asking respondents whether they seek advice about (i) grant getting and (ii) publishing from their PhD advisors and postdoctoral supervisors. CFAs are conducted to see if the two binary variables contribute to measure junior scientists' mentoring resource reception from their PhD advisors and postdoctoral supervisors in the form of seeking advice on research, and the results support the significant contribution.

Seeking advice on faculty workload within & outside the department or university. Four variables indicating whether junior scientists have sought advice (coded as 1 as yes and 0 as no) from their PhD advisors and postdoctoral supervisors on faculty workload within and outside the department or university are created. Two variables indicating seeking advice on faculty workload within the department or university from PhD advisors and postdoctoral supervisors are generated by factoring three survey questions asking respondents whether they seek advice on (i) departmental politics, (ii) student-related issue, and (iii) interactions with colleagues. Two variables indicating seeking advice on faculty workload outside the department or university from PhD advisors and postdoctoral supervisors are created by using two survey questions that are whether respondents typically seek advice on (i) collaborating with industry or government and (ii) work/family balance. It would be meaningful to have the variables in the model because they can capture effects of psychosocial mentoring resources and examine the extent of such effects on junior STEM scientists' career advancement.

Table 5 summarizes how independent variables are measured from the survey questions. Table 6 shows the descriptive statistics of the independent variables.

Table 5.

Summary of Independent Variables: Gender and Mentoring Resources

Variable	Survey question	Measure
1. Gender		
Junior STEM scientists as female	Are you…?	1=Female 0=Male
Female PhD advisor	Who was your dissertation chair?	1=Female 0=Male
Female postdoctoral supervisor	Who was your most recent post-doc supervisor?	1=Female 0=Male
2. Mentoring resource from PhD advisor only		
Help on job searching	During your first faculty job search, did your dissertation advisor do any of the following? (Check all that apply) 1. Made phone calls for job search 2. Wrote recommendation letter(s) 3. Defended your career choices with colleagues 4. Gave advice about how to negotiate	1=Yes 0=No
Seeking advice on job searching	Did your dissertation advisor advise you to seek any of the following? (Check all that apply) 1. Postdoctoral position 2. Research-intensive position 3. Teaching-intensive position 4. Non-academic position 5. More competitive position than you were interested in	1=Yes 0=No
3. Mentoring resource from PhD advisors and postdoctoral supervisors		
Research collaboration	[From your PhD advisor or the most recent postdoctoral supervisors*], what types of collaborations have you had with them over the past two academic years? 1. Research grant proposal 2. Teaching or curricular grant proposal 3. Published one or articles together	1=Yes 0=No
Help on career development	Please indicate if [your PhD advisor or the most recent postdoctoral supervisor has*]: 1. Reviewed your papers or proposals prior to submission (on which they were not a co-author) 2. Invited you to join a teaching or research grant proposal team 3. Introduced you to potential research collaborators 4. Recommended you as an invited speaker/panel member 5. Provided you with research or other funding	1=Yes 0=No
Seeking advice on research	Generally, what advice do you typically seek from [your PhD advisor or the most recent postdoctoral supervisor*]? 1. Grant getting 2. Publishing	1=Yes 0=No
Seeking advice on faculty	Generally, what advice do you typically seek from [your	

workload within the department or university	PhD advisor or the most recent postdoctoral supervisor*]? 1. Departmental politics 2. Student related issues 3. Interactions with colleagues
Seeking advice on workload outside the department or university	Generally, what advice do you typically seek from [your PhD advisor or the most recent postdoctoral supervisor*]? 1. Collaborating with industry or government 2. Work/family balance

* Note: Variables indicating whether the individual is their PhD advisor and their most recent postdoctoral supervisor are used.

Table 6.

Summary Statistics of Independent Variables

	N	Mean	Std. Dev.	Min	Max
1. Gender					
Junior STEM scientists	3,968	0.43	0.49	0	1
PhD advisor	3,482	0.11	0.32	0	1
Postdoctoral supervisor	2,050	0.16	0.36	0	1
2. Mentoring resource from PhD advisor only					
Help on job searching					
Made phone calls for job search	3,968	0.08	0.28	0	1
Wrote recommendation letter(s)	3,968	0.84	0.37	0	1
Defended your career choices with colleagues	3,968	0.08	0.28	0	1
Gave advice about how to negotiate	3,968	0.22	0.42	0	1
Seeking advice on job searching – RI position					
Postdoctoral position	3,968	0.46	0.50	0	1
Research-intensive position	3,968	0.36	0.48	0	1
More competitive position than you were interested in	3,968	0.1	0.30	0	1
Seeking advice on job searching – TI position					
Teaching-intensive position	3,968	0.15	0.35	0	1
Non-academic position	3,968	0.04	0.20	0	1
Less competitive position than you were interested in	3,968	0.04	0.19	0	1
3. Mentoring resource from PhD advisors and postdoctoral supervisors					
Research collaboration with PhD advisor					
Research grant proposal	3,968	0.05	0.21	0	1
Teaching or curricular grant proposal	3,968	0.01	0.09	0	1
Published one or articles together	3,968	0.14	0.35	0	1
Research collaboration with postdoctoral					

supervisor					
Research grant proposal	3,968	0.05	0.21	0	1
Teaching or curricular grant proposal	3,968	0	0.07	0	1
Published one or articles together	3,968	0.11	0.31	0	1
Help on career development from PhD advisor					
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	3,968	0.24	0.43	0	1
Invited you to join a teaching or research grant proposal team	3,968	0.27	0.44	0	1
Introduced you to potential research collaborators	3,968	0.09	0.29	0	1
Recommended you as an invited speaker/panel member	3,968	0.16	0.37	0	1
Provided you with research or other funding	3,968	0.23	0.42	0	1
Help on career development from postdoctoral supervisor					
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	3,968	0.14	0.35	0	1
Invited you to join a teaching or research grant proposal team	3,968	0.18	0.39	0	1
Introduced you to potential research collaborators	3,968	0.08	0.27	0	1
Recommended you as an invited speaker/panel member	3,968	0.11	0.32	0	1
Provided you with research or other funding	3,968	0.17	0.38	0	1
Seeking advice on research from PhD advisor					
Grant getting	3,968	0.18	0.38	0	1
Publishing	3,968	0.28	0.45	0	1
Seeking advice on research from postdoctoral supervisor					
Grant getting	3,968	0.15	0.36	0	1
Publishing	3,968	0.18	0.39	0	1
Seeking advice on faculty workload within the department or university from PhD advisor					
Departmental politics	3,968	0.08	0.26	0	1
Student related issues	3,968	0.06	0.23	0	1
Interactions with colleagues	3,968	0.10	0.29	0	1
Seeking advice on faculty workload within the department or university from postdoctoral supervisor					
Departmental politics	3,968	0.04	0.21	0	1
Student related issues	3,968	0.03	0.17	0	1
Interactions with colleagues	3,968	0.06	0.24	0	1
Seeking advice on workload outside the department or university from PhD advisor					
Collaborating with industry or government	3,968	0.04	0.20	0	1
Work/family balance	3,968	0.07	0.26	0	1
Seeking advice on workload outside the department or university postdoctoral supervisor					
Collaborating with industry or government	3,968	0.03	0.18	0	1

Work/family balance	3,968	0.04	0.21	0	1

4.4.3. Control variables

In addition to the gender and mentoring resources from PhD advisors and postdoctoral supervisors, several other factors may impact the STEM faculty's time to obtain the first tenure-track positions. Such factors include research productivity, type of institution where faculty members were hired, demographics such race and PhD cohort, domestic caregiving responsibility, and preferred career choice when receiving PhD. These factors can directly contribute to the time to obtain the first tenure-track positions among STEM faculty, or indirectly contribute to the dependent variable by having impacts on other explanatory factors (e.g., the proportion of respondents proceeding with postdoctoral positions, creating of varying probability of having same or opposite gender PhD advisor or postdoctoral supervisors). The contributions may result in first academic job attainment outcomes among STEM faculty. Therefore, such factors will serve as control variables to identify the isolated impacts of the gender and resource from PhD advisors and postdoctoral supervisors.

4.4.3.1. *Research productivity*

Research productivity is controlled for because career progress decisions in academia including hiring faculty members or conferring promotion are based mainly on one's research productivity. Research productivity is captured by survey questions asking respondents about the type of articles that they have published over a lifetime[4]. In the context of the initial job attainment in academia, this study uses a bibliometric variable

[4] Indicating five document types: Peer-reviewed journal article, Letter, Note, Working paper, Review.

indicating the volume of peer-reviewed journal articles. To capture impacts of pre-tenure-track research productivity on obtaining the first tenure-track position, articles published in the year, or years, before faculty members got the position are included. Thus, two bibliometric variables are included in total to capture document types as well as the time the document was being proceeded or published. First, ***pre-PhD research productivity*** is captured by the number of peer-reviewed journal articles published in the year that respondents obtained PhD or earlier. It ranges from 0 to 160. Second research productivity variable, ***postdoc research productivity***, is captured by the number of peer-reviewed journal articles published between the year when respondents obtained PhD and the year of obtaining the first tenure-track positions. It ranges from 0 to 288.

4.4.3.2. Discipline and institution type

STEM discipline. To indicate discipline effects, four dummy variables of ***STEM discipline*** are used: Biology (1=yes), Biochemistry (1=yes), Civil Engineering (1=yes), Math (1=yes). There are two main reasons to have the discipline effect variable. First, female STEM scholars' show better career advancement outcome in discipline with higher proportion of female scientists. Female scientists in universities and departments with more representation are more likely to have more support (Etzkowitz et al., 2000) because such organizations pay more attentions to gender equity. Second rationale to examine discipline effects in this research model is that the proportion of PhD recipients who proceed with postdoctoral training greatly vary by discipline, which leads to the difference in the time to get tenure-track positions. According to the data set used for this study, the proportion of PhD recipients who proceed with postdoctoral training is higher in disciplines with a higher representation of women such as Biology (81.51%) or

Biochemistry (85.76%). However, PhD recipients in disciplines with a relatively lower representation of women the proportion are less likely to proceed with postdoctoral training: Civil Engineering (32.72%) and Math (40.78%). In the survey, discipline information was collected through the fill-in-the-blank question as follow; 'what is your broad academic discipline?' Various types of STEM disciplines (e.g., biological sciences, chemistry, computer science, earth and atmospheric sciences, electrical engineering, and physics) were recoded into four categories based on the level of female representation. For example, Biology and Biochemistry are characterized as 'high,' Mathematics is as 'medium,' and Civil Engineering is a STEM discipline that is characterized by 'low' levels of female representation (NSF, 2009).

Current institution type. In addition to the type of PhD institutions, I also generated a variable indicating the type of current institutions where STEM faculty work because the type of hiring institutions can also determine STEM faculty's initial job attainment outcomes. The current institution type variable is coded as 1 if they are in RI/RE institutions and 0 otherwise.

4.4.3.3. Demographic factors

PhD Cohort. The year that respondents received their PhD is also controlled for. The job martket envionment and requirements for faculty hiring may not be the same for those who received PhDs in 1960s and 2000s. In fact, the length of time to have a job or get promoted is longer for younger PhD cohorts (National Research Council, 2010). PhD cohort can also approximate scholarly experiences and achievements. The year that respondents received PhD ranges from 1960 to 2011. PhD cohort variable is coded into eight categories based on the percentile of the PhD year variable: received PhD in 1975 and earlier (=1), 1976-1980 (=2), 1981-1985 (=3), 1986-1990 (=4), 1991-1995 (=5), 1996-2000 (=6), 2001-2005 (=7), and 2006 and later (=8). In terms of the distribution of the year that respondents received their PhDs, PhD cohort coded 1, 2, and 3 are those who are in 25th percentile group, 4 and 5 are in 25th – 50th percentile, and PhD cohort coded 6, 7, and 8 are in 75th percentile and above.

4.4.3.4. Domestic caregiving responsibility: child-bearing and marital status

Childcare is one of the most often discussed factors when discussing female academic scientists' delayed career progress (Fox, Fonseca, & Bao, 2011; Misra et al., 2010; Newton, 2013; Ward & Wolf-Wendel, 2004). Compared with female scientists who do not have children, it takes longer for faculty members who are mothers to be promoted (Misra et al., 2010). In considering the research context of junior STEM faculty members' time to obtain the first tenure-track position, two childcare variables are incorporated. The first childcare variable is ***having children during PhD*** that indicates whether junior STEM faculty had children while they were in their PhD programs. PhD kid variable is coded one if the respondents have children who were born anytime before receiving PhDs and zero otherwise. The second childcare variable is ***having children during postdoc training.*** It captures whether junior STEM scientists had children during the postdoctoral period. This variable is also binary. It is coded one if the respondents have children who were born anytime between the year when respondents received their PhDs and got the first tenure-track position and zero otherwise.

In the survey, respondents reported their child(ren)'s age upon the question as following: 'If you have dependent children, what are their current ages?' Respondents could provide multiple age information up to five if they have more than two children. I created a variable indicating children's born year from the child(ren)'s age variable. Then I compared the born year to the year when respondents received PhD or when they obtained the first tenure-track positions to indicate whether the child(ren) was (were) born before the respondents received PhD or obtain the first tenure-track position.

In addition to the childcare variables, ***marital status*** is also incorporated to capture non-childcare-related domestic caregiving responsibility that is one of the critical factors for academic scientists, especially for female scientists, delaying in job attainments (Misra et al., 2010). Using a survey question asking respondents about their marital status, domestic partnership variable is recoded into a binary variable; it is coded one if respondents reported that they were married or living in a marriage-like relationship and zero if they reported that they were single, separated, divorced, or widowed.

4.4.3.5. Preferred career choice as finishing PhD

The last control variable used in the research model is whether preferred career choice of a Research Intensive academic tenure-track position after finishing the PhD. It is coded 1 as 'preferred career choice as research intensive academic tenure-track position as finishing PhD' and 0 'preferred career choice as teaching intensive academic position, industry, government as finishing PhD.' It is controlled because if one's career choice is somewhere other than research intensive tenure-track positions (e.g., teaching intensive or non-tenure-track academic position, industry, government), they might prepare for the job market differently. For example, they might have less peer-reviewed journal publications, pursue more practical experiences during their PhD programs, or they might seek and receive different types of network resources from PhD advisors as compared to those who pursue an academic career. Also, even if STEM faculty ended up obtaining tenure-track positions, variation of the time to get the first tenure-track positions for them would be different from that for those whose preferred career choice were tenure-track position. The proportion of proceeding with postdocs will vary because main purposes of doing postdocs are "to promote research and to foster career development of young scholars" particularly in the academia (Su, 2013, p. 241).

Table 7 summarizes the survey questions and measurements of the control variables. Table 8 shows the descriptive statistics of the control variables.

Table 7.

Summary of Control Variables

Variable	Survey question	Measure
1. Research productivity		
Total number of peer-reviewed journal articles published during and before PhD	1. Please list peer-reviewed journal articles that you have published over a lifetime. 2. In what year was the article published?	Number calculated by counting the peer-reviewed articles published before receiving PhD
Total number of peer-reviewed journal articles published during postdoctoral period	Please list peer-reviewed journal articles that you have published over a lifetime.	Number calculated by counting the peer-reviewed articles published after receiving PhD and before getting tenure-track position
2. STEM discipline	What is your broad academic discipline?[1]	1=Yes 0=No
Biology		
Biochemistry		
Civil Engineering		
Math		

3. PhD cohort	In what year did you complete your PhD?	Ordinal variable is created based on the percentile of the PhD year: 1=Received PhD in 1975 and earlier 2=1976-1980, 3=1981-1985, 4=1986-1990 5=1991-1995 6=1996-2000 7=2001-2005 8=Received PhD in 2006 and later
4. Current institution type		1=R1 universities (Highest research activity) 2=R2 universities (Higher research activity) 3=R3 universities (Moderate research activity) 4=Non-RI/RE universities
5. Having children during PhD	1. If you have dependent children, what are their current ages? 2. In what year [yyyy] did you complete your PhD?	Dummy variable is created: 1=Having children who were before receiving PhD 0=Others
6. Having children during postdoctoral training	1. If you have dependent children, what are their current ages? 2. In what year [yyyy] did you complete your PhD? 3. In what year [yyyy] did you begin your first tenure-track position	Dummy variable is created: 1=Having children who were born after PhD and before obtaining tenure-track position 0=Others
7. Marital status	Are you currently...? 1= Married 2= Living in a marriage-like relationship 3= Widowed 4= Divorced 5= Separated 6= Single	Dummy variable is created: 1=Having domestic partnership (married & living in a marriage-like relationship) 0= Not having domestic partnership (single, separated, divorced, widowed)
8. Preferred career choice as finishing PhD	As you were finishing your PhD, what was your preferred career choice? 1. Tenure track faculty position in a research intensive environment 2. Tenure track faculty position in a teaching intensive environment 3. Position in industry 4. Position in government 5. Non-tenure-track academic position 6. Other	Dummy variable is created: 1= Tenure track faculty position in a research intensive environment 0=Others

Note: 1. Four dummy variables indicating STEM discipline are created based on the level of female representation (NSF, 2009).

Table 8.

Summary Statistics of Control Variables

	N	Mean	Std. Dev.	Min	Max
1. Research productivity					
Total number of peer-reviewed journal articles published during and before PhD	2,829	2.87	6.36	0	160
Total number of peer-reviewed journal articles published during postdoctoral period	2,829	3.45	8.62	0	288
2. STEM discipline					
Biology	3,597	0.38	0.49	0	1
Biochemistry	3,597	0.16	0.37	0	1
Civil Engineering	3,597	0.20	0.40	0	1
Math	3,597	0.26	0.44	0	1
3. PhD cohort	3,827	6.02	2.09	1	9
4. Current institution type	3,964	0.45	0.50	0	1
5. Having children during PhD	3,968	0.21	0.41	0	1
6. Having children during postdoctoral training	3,968	0.18	0.39	0	1
7. Marital status	3,324	0.85	0.35	0	1
8. Preferred career choice as finishing PhD	3,855	0.52	0.50	0	1
9. Race	3,968	2.11	1.55	1	6

4.5. Description of missing data

Missing values are a common issue for social science studies using survey analysis, experimental designs, and administrative data (Juster & Smith, 1998; Acock, 2005). In a typical data set, information can be missing either at variable or case levels because respondents often refuse or forget to answer some questions in self-administered surveys (Allison, 2003; Fox-Wasylyshyn & El-Masri, 2005).

Missing data cause problems. Missing data leads to loss of statistical power because it reduces the number of samples used in data analysis that is required for higher level of statistical power (Roth, 1994). Missing data can bias parameter estimates, which prevents researchers to conduct robust statistical tests to discover relationships in the data (Roth, 1994). Missing data is what needs to be handled because standard data analysis methods require each variable with values and cannot be completed when data is missing (Allison, 2000). Thus, it is important to handle missing data prior to the data analysis in considering validity and generalizability of research findings. Handling missing data requires two items of essential information that are the amount and nature of missing data and the techniques of managing the missing data including the rationale to use selected techniques (Schlomer, Bauman, & Card, 2010).

Table 9 shows the extent of missing data. Dependent variable, number of years to obtain the first tenure-track positions after receiving PhDs, has 4.3% of cases with missing values. PhD advisors' and postdoctoral supervisors' gender have around 14% cases with missing data. Four STEM discipline variables have 10.3% of missing data respectively. Marital status variable has 19.4% of missing cases. For other control variables such as PhD cohort, current institution type, and career choice as receiving PhD has less than 5% of missing cases.

Table 9.

Extent of Missing Data in Percentages for Key Variables

	N	Number Missing	Percent Missing
1. Number of years to obtain the first tenure-track position after PhD	3,968	169	4.3%
2. Female PhD advisor	3482	486	14.0%
3. Female postdoctoral supervisor*	2,050	298	14.5%
4. Biology	3,597	371	10.3%
5. Biochemistry	3,597	371	10.3%
6. Civil Engineering	3,597	371	10.3%
7. Math	3,597	371	10.3%
8. Total number of peer-reviewed journal articles published during postdoctoral period	2,829	1,139	40.3%
9. Total number of peer-reviewed journal articles published during and before PhD	2,829	1,139	40.3%
10. PhD cohort	3,827	141	3.7%

11. Current institution type	3,964	4	0.1%
12. Marital status	3,324	644	19.4%
13. Preferred career choice as finishing PhD	3,855	113	2.9%

* Note: When reporting missing cases in the female postdoctoral supervisor variable, only respondents who completed postdoctoral trainings are included. Respondents who got a job after receiving PhD without a postdoctoral training are not included.

There is no consensus about the cutoff point that the extent of missing data becomes problematic (Schlomer, Bauman, & Card, 2010). One of the strictest cutoff points for missing data is 5% (Schafer, 1999). Schafer (1999) asserted that a missing rate of 5% or less is negligible. Other researchers suggest that statistical analyses are more likely to be biased if missing data exceed 10% (Bennett, 2001), 20% (Peng, Harwell, Liou, & Ehman, 2006; Schlomer, Bauman, & Card, 2010), and 40% (Raymond & Roberts, 1987) of the data. Roth (1994) notes that data imputation techniques to address missing data can be used when less than 20% cases of data are missing. The extent of missing data of the key variables for this study does not seem to be problematic. However, it is important to pay attention to the two control variables indicating the number of peer-reviewed journal article publications because both variables have 40.3% missing cases. Paul Allison (2012), one of the most cited researchers about the quantitative research methods, affirms that researchers can use data imputation techniques even with 50% cases of data are missing by increasing the number of imputed data sets. According to Allison (2012), five imputed data sets produce point estimates that are 91% as efficient and ten imputed data sets produce 95% efficiency as compared to the infinite number of imputations. Graham, Olchowski, & Gilreath’s (2007) simulation results support Allison’s argument. They recommend generating 20 imputed data sets for 10% to 30% missing information, and 40 imputed data sets for 50% missing information (Graham et al., 2007). Given the support from those scholars, multiple imputation technique is used to address missing data in this study.

4.6. Data analysis method: Structural Equation Modeling (SEM)

Structural Equation Modeling (SEM) is used as the primary analysis tool to test hypotheses about various factors influence the time to obtain the first tenure track positions among academic STEM faculty.

SEM can be conceptualized as an extension of the multiple regression analysis that estimates such regression equations simultaneously (Hoyle, 2011; Jahanshahi, Jin, Williams, 2015). SEM facilitates interpreting directions and strengths of causal relations among the multiple predictors and outcomes in the regression (Carter, Murji, Shore, & Rourke, 2003; Hoyle, 2012). In fact, one of the great emphases of SEM is to represent and model complex causal and interactive relationships in a combined framework. To convey and visualize the details of the multiple equations to be estimated using SEM, the path diagram is used (Hoyle, 2011). SEM's path analysis can capture both direct and indirect effects among variables. Direct effects characterize the causal relation between a single independent and a dependent variable within a path diagram model (Hoyle, 2011). At the same time, the dependent variable in a direct effect can be the independent variable in another direct effect (Hoyle, 2011), which represents the indirect effect in SEM. Indirect (i.e., mediating) effects captures the impacts of an independent variable on a dependent variable through one or more mediating variables in the path diagram (Hoyle, 2012; Jahanshahi et al., 2015).

SEM's path analysis and its capacity to capture direct and indirect effects among variables are closely relevant to a key reason for using SEM in this research. Multiple interactive and mediating effects among the gender of junior STEM scholars, the gender of their PhD advisors and postdoctoral supervisors, and network resource from the advisors and supervisors on junior STEM faculty's time to obtain the first tenure-track positions are hypothesized in the model. For example, in this study, path analysis model in SEM estimates effects of the gender of junior STEM faculty on time to obtain the first tenure-track position. The model also captures the gender effects on network resource provision from PhD advisors and postdoctoral supervisors, as well as network resource effects on time to obtain the first tenure-track position respectively. Consequently, two direct effects (i.e., gender & network resource and network resource & time to get the position) and indirect effects (i.e., gender effects on time to get the position through network resource effects) can be measured through path analysis in SEM.

Along with the path analysis, using latent variables in a measurement model is another key reason for using SEM in this study. A latent variable is defined as an unobserved variable and represented as a function of observed variables (Hoyle, 2011). Based on hypotheses and factor analyses from the previous studies, researchers can decide which constituent factors that they include for the latent variables in their model (Jahanshahi et al., 2015; Wang & Wang, 2012). The capacity to estimate such abstract phenomena is one of the key distinctive characteristics of SEM because the latent variables can embody theoretical constructs that are not measured directly. Other statistical methods can only use observed variables that are represented by values, and the case-level data cannot do so (Byrne, 2012; Schumacker & Lomax, 2004).

Theoretical models in this study represent an integration of status characteristics theory, social network theory, and social capital theory to predict the effect of gender and network resources on the initial job attainment outcomes in academic STEM. Thus, SEM with latent variables allows to include the multiple theories into the analyses and to predict junior STEM faculty's time to obtain the first tenure-track positions. Mplus Version 7.31 is used for the analysis.

5. Findings

5.1. Introduction

The goal of this study is to understand the collective effects of gender, mentoring resource, and gender homophily on STEM faculty early stage career advancement outcome. In Chapter 3, seven sets of hypotheses were developed to test the effects based on the theoretical and empirical foundations. In the following chapter, data, measure, and research methods were discussed to conduct the empirical analysis. The goal of this chapter is to present two empirical models testing hypotheses presented in the previous chapter and the results of the models.

To achieve this goal, the following section discusses more detailed empirical models that highlight the relationship between gender, mentoring resource, gender homophily, and the number of years to get tenure-track positions among STEM faculty members who completed postdoctoral training before getting the position and who moved to faculty position right after receiving PhD. Then, descriptive statistics results will be discussed to present univariate analysis findings. The following section presents and interprets the results of the structural equation modeling analysis examining the influence of gender, mentoring resource, gender homophily, and the number of years to get tenure-track positions among STEM faculty members. In this part, it will be presented whether the hypothesized relationships are supported. This chapter will also present additional findings of control variables in the models.

5.2. Empirical model

In this study, hypothesized relationships are tested in two sets of empirical models. The first model predicts the influence of gender, mentoring resource, gender homophily on STEM faculty early stage career advancement among those who got tenure-track positions without having postdoctoral training (‘PhD only group’ hereafter). The second model predicts the same influence among those who completed postdoctoral trainings before obtaining tenure-track positions (‘postdoc group’ hereafter). Among the final sample, 40% of reported that they had not completed postdoctoral training and 60% of respondents reported that they had completed one. Postdoctoral training experiences lead to significantly different career advancement outcome, the number of years to obtain tenure-track position, for the two groups. For PhD only group, it took 1.1 years to get a tenure-track job while it took 4.5 years for postdoc group ($t=-27.7$, $p<0.000$). The average number of years to obtain tenure-track position for the final sample including both postdoc group and PhD only group is 3.15 years. In addition, different types of mentoring help and support variables are included in PhD only group model and postdoc models in predicting mentoring effects on STEM faculty early stage career advancement outcomes. It is because respondents in the PhD only group received mentoring help and support from PhD advisors only while postdoc group received one from PhD advisors and postdoctoral supervisors. Figures 4 and 5 shown below depict the hypothesized relationship in two models.

5.2.1. PhD only group model

Figure 4 includes seven hypotheses that are to test the direct effects of gender (H1) and mentoring resource (H2-1) on time to obtain tenure-track positions among STEM faculty members who moved to the faculty position right after receiving PhD. The model also illustrates direct gender effects on the mentoring resource from PhD advisors (H3-1) and gender homophily in mentoring dyads (H4-1). This PhD only model shows two indirect effects as well. Hypothesis 5-1 will examine effects of female PhD advisor–female mentee relationships on the reception of mentoring resource as compared to male PhD advisor–male mentee relationships. The last indirect effect presented in the model is to examine same-gender mentoring effects on time to obtain tenure-track positions among STEM faculty members through mentoring resource provision (H6-1). Non-hypothesized control variables are also shown in the model.

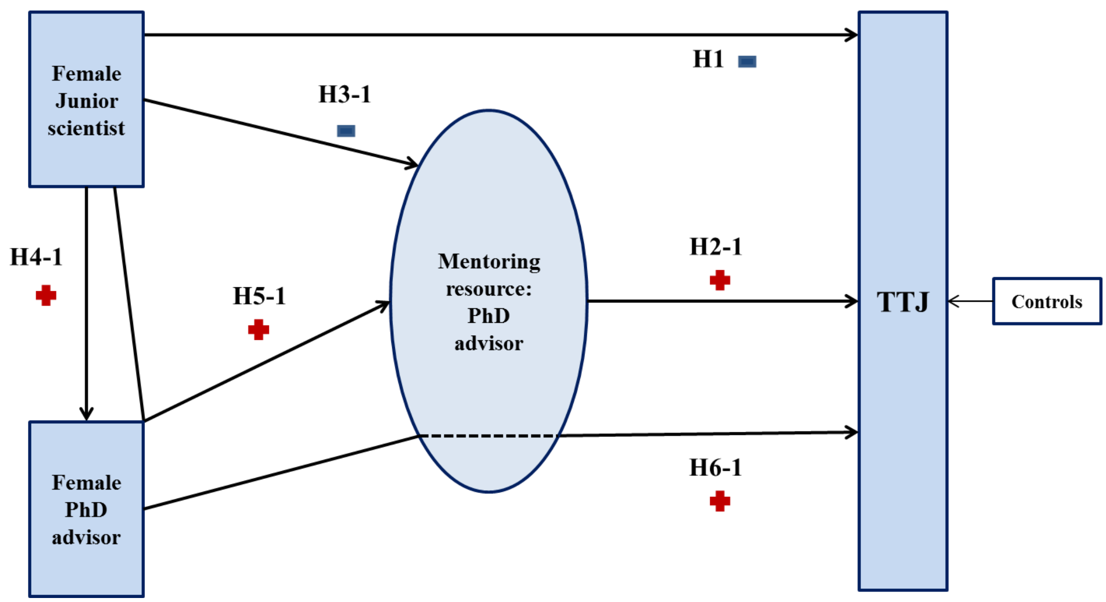

Figure 4. Conceptual Model Illustrating Relationships between Gender, Mentoring Resource, Gender Homophily, and STEM Faculty Early Stage Career Advancement Outcome among Those Who Got Tenure-track Positions without Having Postdoctoral Training

5.2.2. Postdoctoral group model

In addition to the seven hypotheses presented in Figure 4, Figure 5 includes six more hypotheses that are to test the direct effects of mentoring resource from postdoctoral supervisors (H2-2) on time to obtain tenure-track positions among STEM faculty members who completed postdoctoral training before obtaining the positions. The postdoc model also illustrates direct gender effects on the mentoring resource from postdoctoral supervisors (H3-2) and gender homophily in mentoring dyads (H4-2). Postdoc model also shows indirect effects. Hypothesis 5-1 is to examine effects of female postdoctoral supervisor–female postdoctoral trainee mentoring relationships about receiving mentoring resource as compared to male-male relationships. The last indirect effect presented in the postdoc model is to examine same-gender mentoring effects on time to obtain tenure-track positions among STEM faculty members through mentoring resource from postdoctoral supervisors (H6-2). As in the PhD model, postdoc model also presents non-hypothesized effects of control variables.

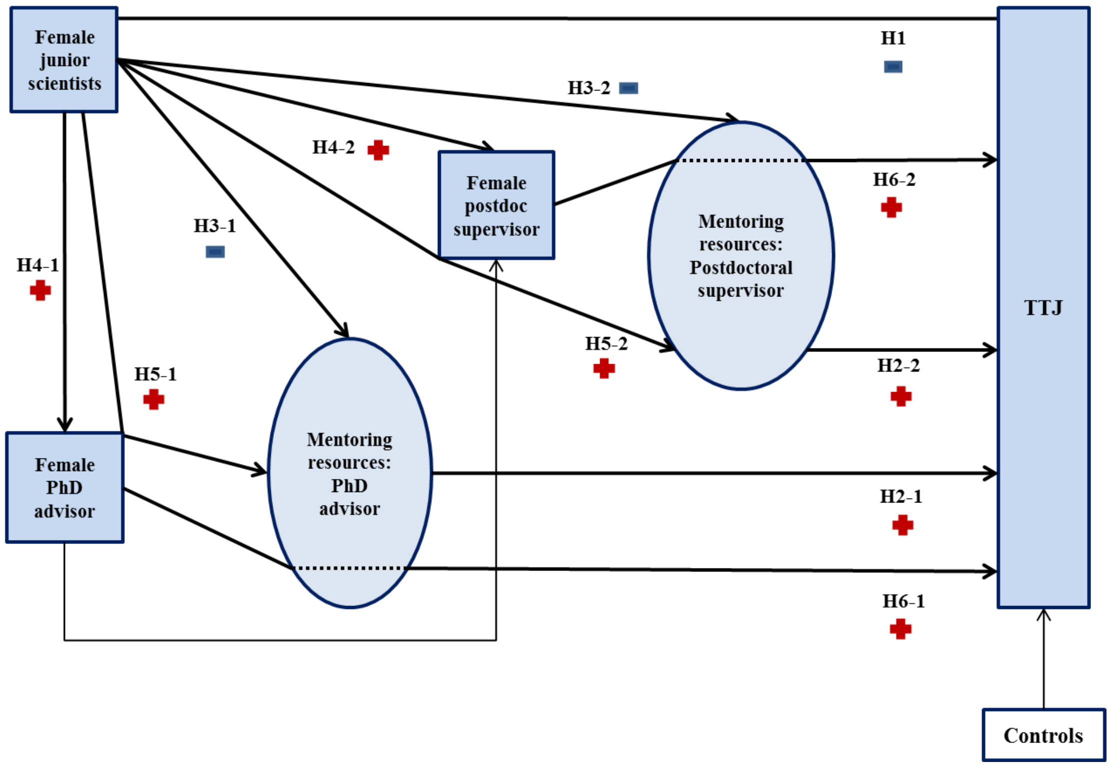

Figure 5. Empirical Model Illustrating Relationships between Gender, Mentoring Resource, Gender Homophily, and Stem Faculty Early Stage Career Advancement Outcome among Those Who Completed Postdoctoral Trainings before Obtaining Tenure-track Positions

5.3. Descriptive statistics

The first step of empirical analysis of the data is a review of the descriptive statistics to present univariate analysis findings. As the previous section presents two different empirical models for the PhD only group and postdoctoral group, this section presents two sets of descriptive statistics findings to capture the difference between two groups.

5.3.1. Dependent variable: Number of years to obtain the tenure-track position

Table 10 presents descriptive statistics of the dependent variable of the PhD only group and postdoctoral group. In the PhD model, the final sample of 1,561 STEM faculty members is included. The postdoctoral group has the sample of 2,346 STEM faculty members. As discussed in the previous section, the average time to obtain the first tenure-track position of the PhD only group is 1.08 years while it is 4.5 years for respondents in the postdoc group. The mean difference between two groups is supported by t-test results ($p<0.000$). Descriptive statistics results also show gender differences in the number of years to obtain the first tenure-track position both in PhD only group and postdoc group. For the PhD only group, the average time to obtain the position is 0.7 year for female junior scientists and 1.3 years and the mean difference is significant at 0.01 thresholds. Female scientists' shorter time to get the first tenure-track position may be closely associated with their initial career choice in non-academic or non-research-intensive academic environment. In the PhD only group, 67.3% (424 out of 630) of the female while 57% (515 out of 903) of male respondents' preferred career choices were tenure-track faculty positions in teaching intensive environment, positions industry and government, or non-tenure-track academic positions. For postdoc group, the average time to obtain the first tenure-track position is 4.63 years for females and 4.41 years for males, and the mean difference is significant at 0.10 level.

Table 10.

Descriptive Statistics of the Dependent Variable: Number of Years to Obtain the First Tenure-track Position After PhD

PhD only group					Postdoc group				
N	**Mean**	**Std. Dev.**	**Min**	**Max**	**N**	**Mean**	**Std. Dev.**	**Min**	**Max**
1,501	1.08^{***}	4.05	-28	42	2,294	4.5^{***}	3.49	-11	26

PhD only group – *female*					Postdoc group – *female*				
N	**Mean**	**Std. Dev.**	**Min**	**Max**	**N**	**Mean**	**Std. Dev.**	**Min**	**Max**
608	0.71**	3.79	-28	25	1,015	4.62†	3.52	-8	26
PhD only group – *male*					**Postdoc group – *male***				
893	1.33**	4.21	-13	42	1,279	4.41†	3.47	-11	24

5.3.2. Gender of junior scientists and mentors

As for the gender of junior STEM scientists, 41% of the sample is female in the PhD only group and 44% in the postdoc group. Descriptive statistics results of gender homophily in mentoring relationships are well captured in Figure 6 through 8. Figure 6 shows the results of the PhD only group. 15.8% of female respondents reported same-gender mentoring relationships with PhD advisors while 91.5% male respondents had the same-gender mentoring relationships.

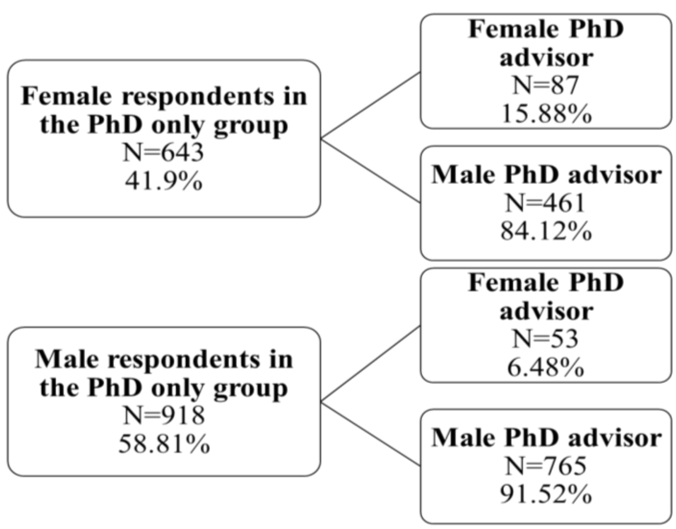

Figure 6. Gender Distribution and Gender Homophily in Mentoring Relationships with PhD Advisors among STEM Faculty Members Who Got Tenure-track Positions without Having Postdoctoral Training

For respondents in the postdoc group (see Figure 7 and 8), gender homophily in mentoring relationships with PhD advisors and postdoctoral supervisors are presented. In the postdoc group, 16.8% of female respondents reported same-gender mentoring relationships with PhD advisors while 91.9% male respondents had the same-gender mentoring relationships. Among female STEM faculty, those who had female PhD advisors are twice more likely to have female postdoctoral supervisors (35.8%) as compared to those who had male PhD advisors (17.5%). Also, male STEM faculty who had female PhD advisors are twice more likely to have female postdoctoral supervisors (23.1%) as compared to those who had male PhD advisors (10.8%).

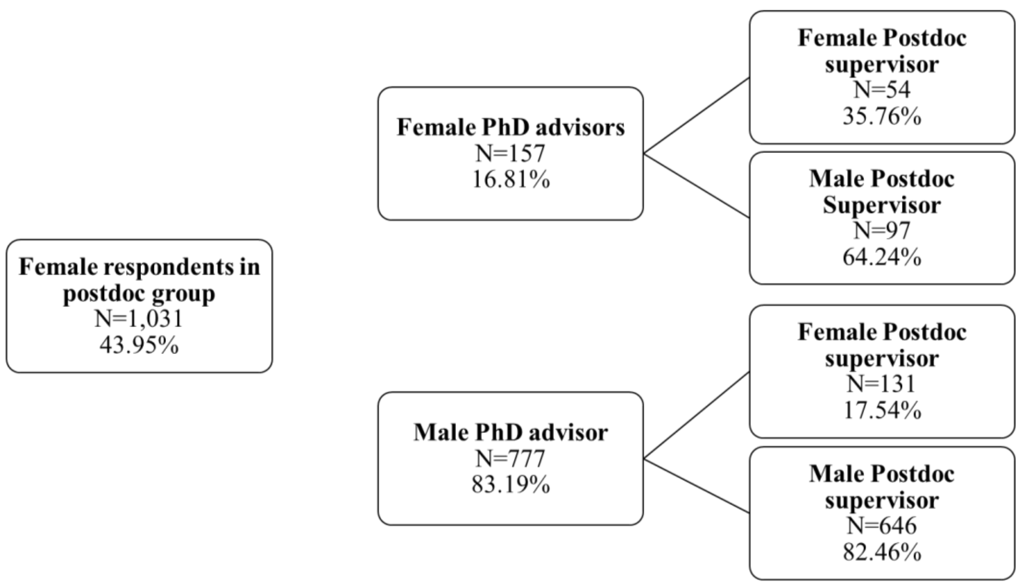

Figure 7. Gender Distribution and Gender Homophily in Mentoring Relationships with PhD Advisors and Postdoctoral Supervisors among Female STEM Faculty Members Who Completed Postdoctoral Trainings before Obtaining Tenure-track Positions

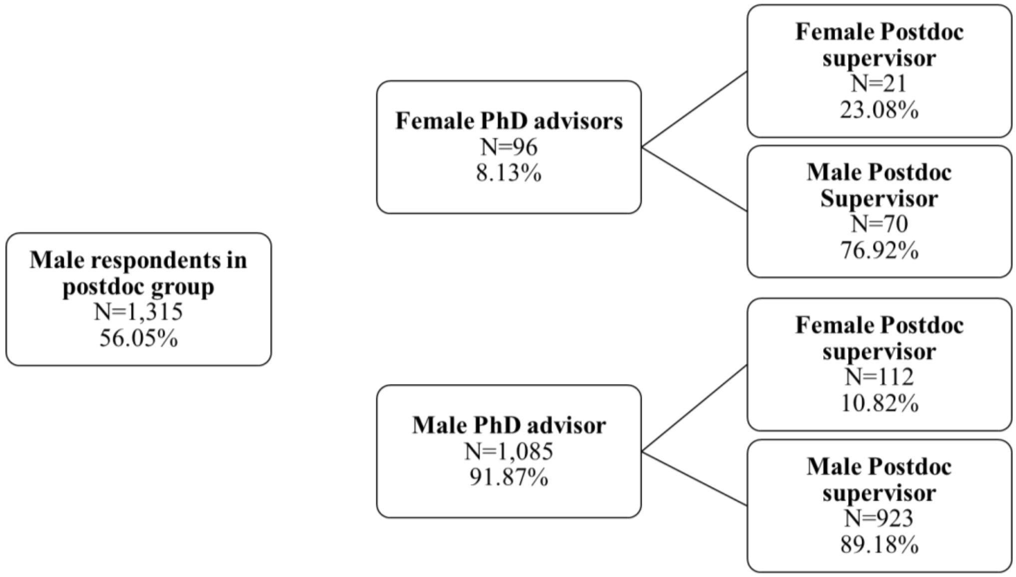

Figure 8. Gender Distribution and Gender Homophily in Mentoring Relationships with PhD Advisors and Postdoctoral Supervisors among Male STEM Faculty Members Who Completed Postdoctoral Trainings before Obtaining Tenure-track Positions

5.3.3. Mentoring resource from PhD advisors: *mentoring resource variables for job searching*

Turning to the mentoring resource from PhD advisors variables, descriptive statistics finds results of three categories of mentoring resource variables for job searching: (i) help on job searching, (ii) seeking advice on searching research-intensive position, and (iii) seeking advice on searching teaching-intensive position.

Table 11 presents descriptive statistics of the independent variables of the PhD only group and postdoctoral group. Descriptive statistics results show that writing recommendation letters during STEM faculty members' first faculty job search is the mentoring resource that most proportion of respondents received. Around 85% of both PhD only group and postdoc group reported that their PhD advisors wrote recommendation letters for them. Less than 10% of respondents of both PhD only group and postdoc group reported that their PhD advisors made phone calls during their first faculty job search or defended their career choices with colleagues. Also, 24.8% (388 out of 1,561) of respondents in the PhD only group reported that their PhD advisors gave them advice about how to negotiate during their first job searching and 21.4% (503 out of 2,346) of respondents in postdoc group reported so ($p<0.05$).

The next two sets of mentoring resources from PhD advisors are about seeking advice on searching research-intensive and teaching-intensive positions. Descriptive statistics results show that a greater proportion of STEM faculty members in the PhD only group reported receiving mentoring resources from PhD advisors regarding seeking advice on searching teaching-intensive positions while more proportion of those in postdoc group reported receiving such mentoring resource regarding research-intensive positions. 64% of respondents in postdoc group reported that they sought advice on searching research-intensive positions while 19% of respondents in the PhD only group reported so ($p<0.000$). As for seeking advice from PhD advisors on searching research-intensive positions, more respondents in the PhD only group received more mentoring resources. 22% of the PhD only group and 10% of postdoc group reported that they sought advice on searching teaching-intensive positions ($p<0.000$). 5% of respondents in the PhD only group and 4% of respondents in the postdoc group sought advice from PhD advisors on searching non-academic positions ($p<0.10$). When it comes to seeking advice on searching less competitive position than respondents were interested in, 4% of the PhD only group and 3% of postdoc group reported that they reached to their PhD advisors ($p<0.10$).

5.3.4. Mentoring resources from PhD advisors: *other mentoring resource variables*

Next, insights into non-job-searching related mentoring resources from PhD advisors and postdoctoral supervisors are presented. Non-job-searching related mentoring resources are grouped into categorized five. The first non-job-searching related mentoring resource is the research collaboration. It is measured by STEM faculty members' experience of writing research grant proposal, writing teaching or curricular grant proposal, and publishing one or more articles with PhD advisors and postdoctoral supervisors. On average, less than 5% of STEM faculty members of the PhD only group and postdoc group reported that they wrote research and teaching grant proposals with their PhD advisors. 16% (253 out of 1,561) of STEM faculty members in the PhD only group and 13% of them (316 out of 2,346) in the postdoc group published one of more articles with their PhD advisors. Descriptive statistics results show that the average proportion of respondents publishing articles with PhD advisors is significantly different between PhD only group and postdoc group ($p<0.05$). It may be that a greater proportion of respondents in the postdoc group publishes articles with their postdoctoral supervisors (18%, 425 out of 2,346) than with their PhD advisors (13%).

The second non-job-searching related mentoring resource is receiving help on career development. It is measured by five survey questions asking whether mentors reviewed respondents' papers or proposals prior to submission, inviting them to join a grant proposal team, introducing them to potential research collaborators, recommending them as invited speakers/panel members, and providing them with funding. Descriptive statistics results show that, from PhD advisors, respondents in the postdoc group are more likely to be recommended as invited speaker/panel members or provided with funding from their PhD advisors while the PhD only group received help on papers or proposals.

The third non-job-searching related mentoring resource is seeking advice on research. Two survey questions are used to measure it. As for seeking advice on publishing, little less than 30% of respondents in both PhD only group and postdoc group reached to their PhD advisors, and there is no significant difference between proportions of respondents between two groups. However, for seeking advice on grant-getting from PhD advisors, postdoc group did more. 21% (485 out of 2,346) of respondents in postdoc group sought advice on grant-getting from their PhD advisors whereas 15% (229 out of 1,561) of respondents in PhD only group did ($p<0.01$). On all two mentoring resources regarding help on career development, more postdoc group respondents seeking advice on grant-getting (25%, 588 out of 2,346) and publishing (31%, 722 out of 2,346) from their postdoctoral supervisors than their PhD advisors.

The fourth non-job-searching related mentoring resource is seeking advice on faculty workload within the department or university from the PhD advisor. It is measured by three questions asking STEM faculty members sought advice from PhD advisors on departmental politics, student related issues, and interactions with colleagues. For all three questions, around 10% of respondents from PhD only group and postdoc group reported that they sought such advice from their PhD advisors. Also, around 10% of respondents in postdoc group reported that they also sought the advice from their postdoctoral supervisors.

The fifth, and the last, non-job-searching related mentoring resource is seeking advice on faculty workload outside the department or the university. It is measured by two survey questions indicating STEM faculty members' experience of seeking advice on collaborating with the industry of government and work/family balance. For both questions, less than 10% of respondents from PhD only group and postdoc group reported that they sought advice on collaborating with industry or government and work/family balance. Although there are not many respondents either in PhD only group or postdoc group seeking advice from PhD advisors about collaborating with industry or government, there is the significant difference between the two groups. More proportion of respondents in the PhD only group (6%) sought advice on collaborating with industry or government from their PhD advisors than those in postdoc group (3%) ($p<0.001$).

Table 11.

Descriptive Statistics of Independent Variables – by PhD Only Group and Postdoc Group

	PhD only group					Postdoc group				
Variables	N	Mean	Std. Dev.	Min	Max	N	Mean	Std. Dev.	Min	Max
Mentoring resource from PhD advisor only: *job-searching-related*										
Help on job searching										
Made phone calls for job search	1,561	0.08	0.27	0	1	2,346	0.09	0.28	0	1
Wrote recommendation letter(s)	1,561	0.84	0.37	0	1	2,346	0.86	0.35	0	1
Defended your career choices with colleagues	1,561	0.09†	0.29	0	1	2,346	0.08†	0.27	0	1
Gave advice about how to negotiate	1,561	0.25*	0.43	0	1	2,346	0.21*	0.41	0	1
Seeking advice on job searching – RI position										
Postdoctoral position	1,561	0.19***	0.39	0	1	2,346	0.64***	0.48	0	1
Research-intensive position	1,561	0.35	0.48	0	1	2,346	0.37	0.48	0	1
More competitive position than you were interested in	1,561	0.11	0.31	0	1	2,346	0.09	0.29	0	1
Seeking advice on job searching – TI position										
Teaching-intensive position	1,561	0.22***	0.42	0	1	2,346	0.10***	0.3	0	1
Non-academic position	1,561	0.05†	0.22	0	1	2,346	0.04†	0.19	0	1
Less competitive position than you were interested in	1,561	0.04†	0.2	0	1	2,346	0.03†	0.18	0	1
Mentoring resource from PhD advisors and postdoctoral supervisors: *non-job-searching-related*										
Research collaboration with PhD advisor										
Research grant proposal	1,561	0.05	0.22	0	1	2,346	0.05	0.21	0	1
Teaching or curricular grant proposal	1,561	0.01	0.11	0	1	2,346	0.01	0.07	0	1
Published one or more articles together	1,561	0.16*	0.37	0	1	2,346	0.13*	0.34	0	1
Research collaboration with postdoctoral supervisor										
Research grant proposal	n/a	n/a	n/a	n/a	n/a	2,346	0.08	0.27	0	1
Teaching or curricular grant proposal	n/a	n/a	n/a	n/a	n/a	2,346	0.01	0.08	0	1
Published one or more articles together	n/a	n/a	n/a	n/a	n/a	2,346	0.18	0.39	0	1
Help on career development from PhD advisor										

Reviewed your papers or proposals prior to submission (on which they were not a co-author)	1,561	0.27*	0.44	0	1	2,346	0.24*	0.42	0	1
Invited you to join a teaching or research grant proposal team	1,561	0.26	0.44	0	1	2,346	0.28	0.45	0	1
Introduced you to potential research collaborators	1,561	0.10	0.3	0	1	2,346	0.10	0.29	0	1
Recommended you as an invited speaker/panel member	1,561	0.15*	0.35	0	1	2,346	0.17*	0.38	0	1
Provided you with research or other funding	1,561	0.21**	0.41	0	1	2,346	0.25**	0.43	0	1
Help on career development from postdoctoral supervisor										
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	n/a	n/a	n/a	n/a	n/a	2,346	0.24	0.43	0	1
Invited you to join a teaching or research grant proposal team	n/a	n/a	n/a	n/a	n/a	2,346	0.31	0.46	0	1
Introduced you to potential research collaborators	n/a	n/a	n/a	n/a	n/a	2,346	0.13	0.34	0	1
Recommended you as an invited speaker/panel member	n/a	n/a	n/a	n/a	n/a	2,346	0.19	0.4	0	1
Provided you with research or other funding	n/a	n/a	n/a	n/a	n/a	2,346	0.29	0.45	0	1
Seeking advice on research from PhD advisor										
Grant getting	1,561	0.15***	0.35	0	1	2,346	0.21***	0.41	0	1
Publishing	1,561	0.29	0.45	0	1	2,346	0.28	0.45	0	1
Seeking advice on research from postdoctoral supervisor										
Grant getting	n/a	n/a	n/a	n/a	n/a	2,346	0.25	0.43	0	1
Publishing	n/a	n/a	n/a	n/a	n/a	2,346	0.31	0.46	0	1
Seeking advice on faculty workload within the department or university from PhD advisor										
Departmental politics	1,561	0.08	0.27	0	1	2,346	0.07	0.26	0	1
Student related issues	1,561	0.06	0.24	0	1	2,346	0.05	0.22	0	1
Interactions with colleagues	1,561	0.10	0.31	0	1	2,346	0.09	0.29	0	1
Seeking advice on faculty workload within the department or university from postdoctoral supervisor										
Departmental politics	n/a	n/a	n/a	n/a	n/a	2,346	0.08	0.26	0	1
Student related issues	n/a	n/a	n/a	n/a	n/a	2,346	0.05	0.22	0	1
Interactions with colleagues	n/a	n/a	n/a	n/a	n/a	2,346	0.11	0.31	0	1

Seeking advice on workload outside the department or university from PhD advisor										
Collaborating with industry or government	1,561	0.06^{***}	0.23	0	1	2,346	0.03^{***}	0.18	0	1
Work/family balance	1,561	0.08	0.27	0	1	2,346	0.08	0.26	0	1
Seeking advice on workload outside the department or university postdoctoral supervisor										
Collaborating with industry or government	n/a	n/a	n/a	n/a	n/a	2,346	0.05	0.23	0	1
Work/family balance	n/a	n/a	n/a	n/a	n/a	2,346	0.08	0.26	0	1

Table 12.

Descriptive Statistics of Independent Variables – by Gender Group

	Female junior scientists					**Male junior scientists**				
Variables	N	Mean	Std. Dev.	Min	Max	N	Mean	Std. Dev.	Min	Max
Mentoring resource from PhD advisor only: ***job-searching-related***										
Help on job searching										
Made phone calls for job search	1,698	0.07	0.25	0	1	2,270	0.10	0.29	0	1
Wrote recommendation letter(s)	1,698	0.83	0.37	0	1	2,270	0.84	0.36	0	1
Defended your career choices with colleagues	1,698	0.08	0.28	0	1	2,270	0.08	0.27	0	1
Gave advice about how to negotiate	1,698	0.23	0.42	0	1	2,270	0.22	0.42	0	1
Seeking advice on job searching – RI position										
Postdoctoral position	1,698	0.46	0.5	0	1	2,270	0.45	0.5	0	1
Research-intensive position	1,698	0.34	0.48	0	1	2,270	0.36	0.48	0	1
More competitive position than you were interested in	1,698	0.12	0.33	0	1	2,270	0.08	0.27	0	1
Seeking advice on job searching – TI position										
Teaching-intensive position	1,698	0.15	0.35	0	1	2,270	0.15	0.36	0	1
Non-academic position	1,698	0.04	0.19	0	1	2,270	0.05	0.22	0	1

Less competitive position than you were interested in	1,698	0.04	0.19	0	1	2,270	0.03	0.18	0	1
Mentoring resource from PhD advisors and postdoctoral supervisors: *non-job-searching-related*										
Research collaboration with PhD advisor										
Research grant proposal	1,698	0.05	0.21	0	1	2,270	0.05	0.22	0	1
Teaching or curricular grant proposal	1,698	0.01	0.08	0	1	2,270	0.01	0.1	0	1
Published one or more articles together	1,698	0.13	0.34	0	1	2,270	0.15	0.36	0	1
Research collaboration with postdoctoral supervisor										
Research grant proposal	1,698	0.05	0.22	0	1	2,270	0.05	0.21	0	1
Teaching or curricular grant proposal	1,698	0.00	0.05	0	1	2,270	0.01	0.07	0	1
Published one or more articles together	1,698	0.11	0.31	0	1	2,270	0.11	0.31	0	1
Help on career development from PhD advisor										
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	1,698	0.24	0.43	0	1	2,270	0.24	0.43	0	1
Invited you to join a teaching or research grant proposal team	1,698	0.27	0.44	0	1	2,270	0.27	0.44	0	1
Introduced you to potential research collaborators	1,698	0.09	0.28	0	1	2,270	0.09	0.29	0	1
Recommended you as an invited speaker/panel member	1,698	0.15	0.36	0	1	2,270	0.17	0.37	0	1
Provided you with research or other funding	1,698	0.22	0.42	0	1	2,270	0.24	0.43	0	1
Help on career development from postdoctoral supervisor										
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	1,698	0.15	0.35	0	1	2,270	0.14	0.35	0	1
Invited you to join a teaching or research grant proposal team	1,698	0.19	0.39	0	1	2,270	0.18	0.38	0	1
Introduced you to potential research collaborators	1,698	0.07	0.26	0	1	2,270	0.08	0.27	0	1
Recommended you as an invited speaker/panel member	1,698	0.11	0.31	0	1	2,270	0.12	0.32	0	1
Provided you with research or other funding	1,698	0.17	0.38	0	1	2,270	0.17	0.38	0	1

Seeking advice on research from PhD advisor										
Grant getting	1,698	0.19	0.39	0	1	2,270	0.17	0.38	0	1
Publishing	1,698	0.28	0.45	0	1	2,270	0.28	0.45	0	1
Seeking advice on research from postdoctoral supervisor										
Grant getting	1,698	0.15	0.36	0	1	2,270	0.15	0.36	0	1
Publishing	1,698	0.19	0.39	0	1	2,270	0.18	0.38	0	1
Seeking advice on faculty workload within the department or university from PhD advisor										
Departmental politics	1,698	0.08	0.28	0	1	2,270	0.07	0.25	0	1
Student related issues	1,698	0.06	0.23	0	1	2,270	0.06	0.23	0	1
Interactions with colleagues	1,698	0.1	0.29	0	1	2,270	0.1	0.3	0	1
Seeking advice on faculty workload within the department or university from postdoctoral supervisor										
Departmental politics	1,698	0.05	0.22	0	1	2,270	0.04	0.2	0	1
Student related issues	1,698	0.04	0.19	0	1	2,270	0.02	0.15	0	1
Interactions with colleagues	1,698	0.06	0.24	0	1	2,270	0.06	0.24	0	1
Seeking advice on workload outside the department or university from PhD advisor										
Collaborating with industry or government	1,698	0.03	0.17	0	1	2,270	0.05	0.22	0	1
Work/family balance	1,698	0.08	0.27	0	1	2,270	0.07	0.26	0	1
Seeking advice on workload outside the department or university postdoctoral supervisor										
Collaborating with industry or government	1,698	0.03	0.17	0	1	2,270	0.03	0.18	0	1
Work/family balance	1,698	0.05	0.22	0	1	2,270	0.04	0.2	0	1
Control variables										
Research productivity – Total number of peer-reviewed journal articles published during and before PhD	1,204	3.16	9.81	0	288	1,625	3.67	7.61	0	82
Research productivity – Total number of peer-reviewed journal articles published during postdoctoral period	1,204	2.6	5.47	0	70	1,625	3.07	6.95	0	160

STEM discipline – Biology	1,551	0.45	0.5	0	1	2,046	0.33	0.47	0	1
STEM discipline – Biochemistry	1,551	0.13	0.34	0	1	2,046	0.18	0.38	0	1
STEM discipline – Civil Engineering	1,551	0.17	0.37	0	1	2,046	0.22	0.42	0	1
STEM discipline – Math	1,551	0.25	0.43	0	1	2,046	0.26	0.44	0	1
PhD cohort	1,634	5.45	1.85	1	8	2,193	4.75	2.09	1	8
Current institution type	1,695	0.47	0.5	0	1	2,269	0.43	0.5	0	1
Having children during PhD	1,698	0.18	0.38	0	1	2,270	0.23	0.42	0	1
Having children during postdoctoral period	1,698	0.17	0.38	0	1	2,270	0.19	0.39	0	1
Marital status	1,438	0.79	0.41	0	1	1,886	0.91	0.29	0	1
Preferred career choice as finishing PhD	1,658	0.46	0.5	0	1	2,197	0.56	0.5	0	1
Race	1,698	1.89	1.46	1	6	2,270	2.27	1.6	1	6

5.3.5. Control variables

In addition to mentoring resources, descriptive statistics contain information on control variables in the model such as research productivity, PhD cohort, current institution type, having children during PhD programs or postdoctoral period, marital status, preferred career choice as respondents finished their PhDs, and race (see Table 12). It would be meaningful to start discussing the variable indicating preferred career choice as STEM faculty members finished their PhD degrees because it is closely associated with differences in the type of mentoring resource that PhD only group and postdoc group as well as time to obtain the first tenure-track position.

31% of respondents in the PhD only group and 61% of those in postdoc group reported that their preferred career choice as they were finishing PhD degrees was tenure-track faculty position in a research-intensive environment, and the difference between two group is statistically different at the 0.001 level. It may explain that more proportion of respondents in the PhD only group receives teaching-related or industry-related help and support from their mentors while the postdoc group is more likely to receive research-related help and support. That postdoc group's preferred career choice as finishing PhD was tenure-track faculty position in a research-intensive environment may explain that more proportion of the postdoc group reported that they worked in the RI/RE institutes than the PhD only group.

As for research productivity, postdoc group publishes more than the PhD only group before and after receiving PhDs. On average, respondents in the PhD only group have 1.02 peer-reviewed journal articles published before receiving PhD while those in postdoc group get 4.73 journal articles published ($p<0.001$). The average number of peer-reviewed journal articles published between the time after receiving PhD and before getting a tenure-track job is 2.32 for those in the PhD only group and 2.92 for postdoc group. The difference is also statistically significant at 0.01 level.

Four categories of STEM discipline is also included as a control variable. In the PhD only group, respondents in Math comprise 40%, Civil Engineering comprises 35%, Biology comprises 19%, and Biochemistry comprises 9% of the sample. In postdoc group, 50% of respondents are in Biology, 22% in Biochemistry, 17% in Math, and 10% in Civil Engineering.

Table 13 presents that the average PhD cohort is around 5, which means that receiving PhD from 1996 and 2000 for both the PhD only group and postdoc group, and yet, the difference is statistically significant at 0.001 level. In the sample, the average proportion of STEM faculty who completed postdoctoral training was stable around 55% before the PhD cohort of 1990, and it has been around 65% since it increased to 66% for the PhD cohort of 1991-1996.

Among three variables indicating domestic caregiving responsibility, descriptive statistics results show that there is no difference between the PhD only group and postdoc group regarding marital status. 86% of respondents in PhD only group and 85% of those in postdoc group reported that they were married or living in a marriage-like relationship. PhD only group and postdoc group show significantly different descriptive statistic results in two childcare variables. More proportion of respondents in the PhD only group had children before receiving PhD while more proportion of those in the postdoc group had children after PhD and before obtaining tenure-track positions.

Table 14 presents descriptive statistics results of gender differences in control variables. Except for two control variables indicating female scientists' representation in the STEM field of Math and having children during postdoctoral period, all control variables show that there are gender differences.

Table 13.

Descriptive Statistics of Control Variables – by PhD Only Group and Postdoc Group

		PhD only group					**Postdoc group**				
		N	Mean	Std. Dev.	Min	Max	N	Mean	Std. Dev.	Min	Max
1.	Research productivity – Total number of peer-reviewed journal articles published during and before PhD	929	1.02^{***}	3.73	0	44	1,863	4.73^{***}	10.05	0	288
2.	Research productivity – Total number of peer-reviewed journal articles published during postdoctoral period	929	2.32^{**}	5.07	0	62	1,863	2.92^{**}	5.71	0	83
3.	STEM discipline – Biology	1,363	0.19	0.39	0	1	2,228	0.50	0.5	0	1
4.	STEM discipline – Biochemistry	1,363	0.06	0.24	0	1	2,228	0.22	0.42	0	1
5.	STEM discipline – Civil Engineering	1,363	0.35	0.48	0	1	2,228	0.10	0.31	0	1
6.	STEM discipline – Math	1,363	0.40	0.49	0	1	2,228	0.17	0.38	0	1
7.	PhD cohort	1,510	5.04^{***}	2.14	1	8	2,312	5.03^{***}	1.94	1	8
8.	Current institution type	1,559	0.38^{***}	0.48	0	1	2,344	0.50^{***}	0.5	0	1
9.	Having children during PhD	1,561	0.28^{***}	0.45	0	1	2,346	0.16^{***}	0.37	0	1
10.	Having children during postdoctoral period	1,561	0.07^{***}	0.26	0	1	2,346	0.26^{***}	0.44	0	1
11.	Marital status	1,313	0.86	0.35	0	1	2,005	0.85	0.35	0	1
12.	Preferred career choice as finishing PhD	1,533	0.39^{***}	0.49	0	1	2,317	0.61^{***}	0.49	0	1
13.	Race	1,561	2.05	1.52	1	6	2,346	2.13	1.56	1	6

Table 14.

Descriptive Statistics of Control Variables – by Gender Group

		Female junior scientists					**Male junior scientists**				
		N	Mean	Std. Dev.	Min	Max	N	Mean	Std. Dev.	Min	Max
1.	Research productivity – Total number of peer-reviewed journal articles published during and before PhD	1204	2.6*	5.47	0	70	1625	3.07*	6.95	0	160
2.	Research productivity – Total number of peer-reviewed journal articles published during postdoctoral period	1204	3.16†	9.81	0	288	1625	3.67†	7.61	0	82
3.	STEM discipline – Biology	1551	0.45***	0.5	0	1	2046	0.33***	0.47	0	1
4.	STEM discipline – Biochemistry	1551	0.13***	0.34	0	1	2046	0.18***	0.38	0	1
5.	STEM discipline – Civil Engineering	1551	0.17***	0.37	0	1	2046	0.22***	0.42	0	1
6.	STEM discipline – Math	1551	0.25	0.43	0	1	2046	0.26	0.44	0	1
7.	PhD cohort	1634	5.45***	1.85	1	8	2193	4.75***	2.09	1	8
8.	Current institution type	1695	0.47**	0.5	0	1	2269	0.43**	0.5	0	1
9.	Having children during PhD	1698	0.18***	0.38	0	1	2270	0.23***	0.42	0	1
10.	Having children during postdoctoral period	1698	0.17	0.38	0	1	2270	0.19	0.39	0	1
11.	Marital status	1438	0.79***	0.41	0	1	1886	0.91***	0.29	0	1
12.	Preferred career choice as finishing PhD	1658	0.46***	0.5	0	1	2197	0.56***	0.5	0	1
13.	Race	1698	1.89***	1.46	1	6	2270	2.27***	1.6	1	6

5.4. Results from structural equation modeling (SEM) predicting academic STEM scientists' early stage career advancement outcome

In this section, findings from structural equation modeling (SEM) are presented and discussed to understand in depth the direct and indirect effects of gender, mentoring, and gender homophily in mentoring dyads on STEM faculty's time to obtain the first tenure-track position.

The goal of structural equation modeling is to provide a quantitative test of a theoretical model. To ensure the robustness of the test results, researchers are encouraged to follow sequential steps to conduct SEM analyses. The first step is to specify the relationship between latent and observed variables in the model, which is referred to as model specification (Hoyle, 2011). As discussed in chapter 4, the model specification was done by conducting CFAs (confirmative factor analysis) to detect structure in the relationship between survey questions representing the mentoring resource reception in order to classify and group them into a single latent factor. In this section, thus, estimates of significance between observed and latent variables indicating mentoring resources from PhD advisors and postdoctoral supervisors in the model (with other latent constructs are in effect) will be discussed.

The second step is the model estimation. The goal of model estimation is to minimize the gap between the observed and estimated covariance matrix (Hoyle, 2012). To achieve the goal, it is important to use the robust model estimator. Weighted least squares means and variance adjusted (WLSMV) estimation is used to analyze the structural model in this study. The WLSMV estimator may be the best option for the model in this study because WLSMV does not assume or require normality of data and is recommended when observed variables have categorical or ordered data, as the variables used in this study do (Brown, 2014; Muthén & Muthén, 2012). In addition, path analyses will also be conducted to examine the direct and indirect relationship between variables in the model using WLSMV estimator.

The third step is to examine the goodness-of-fit for the estimated model. The chi-square test, the comparative fit index (CFI), and the root mean square error of approximation (RMSEA) are widely accepted indices providing information about measurement robustness to evaluate the model fit (Beauducel & Wittmann, 2005; Peterson, Speer, & Hughey, 2006). The significance of the chi-square value at the 0.05 threshold, CFI value exceeding 0.90 (Peterson et al., 2006), RMSEA value of smaller than 0.05 (Browne & Cudeck, 1992) are suggested as indicators of a good fit for the SEM model.

The next section presents findings of SEM model for PhD only group and postdoc group as following the three steps. In line with the empirical models presented in the previous section, SEM models results of PhD only group and postdoc group will be presented in this section. For both groups, multiple imputation (MI) techniques are used for SEM analyses to address missing data and to obtain unbiased estimates (McCleary, 2002). In chapter 4, it was discussed that imputed data sets could be created depending on the extent of missing data to reduce bias and provide valid results. SEM for both PhD only group and postdoc group, ten imputed data sets are generated as Allison[5] (2012) recommended.

5.4.1. SEM analyses among respondents who obtained tenure-track position without postdoctoral training – *PhD only group*

This part presents the findings of the SEM model of the PhD only group. The model tests combined relationship between gender, mentoring resource from PhD advisors, and gender homophily in mentoring dyads on STEM faculty's time to obtain the first tenure-track position among those who got a tenure-track job without postdoctoral training.

5.4.1.1. Measurement model estimates of significance between observed variables and latent constructs: Mentoring resources from PhD advisors

Table 15 shown below lists the measurement model estimates of the significance between latent constructs indicating mentoring resources from PhD advisors and observable variables in the model for the PhD only group. The findings of estimates show that all observed variables in the model with and without using the multiple imputation techniques have significant positive relationships with the latent constructs, indicating that the latent constructs represent the theoretical constructs of mentoring.

Table 15.

Measurement Model Estimates of Significance Between Observed Variance and Latent Constructs for the PhD Only Group

[5] There are two variables indicating the research productivity have 40% of missing data used in this study. I conducted several SEM analyses with 10, 20, 30, and 40 imputed data sets because Graham et al.'s (2007) suggest generating 40 imputed data sets for 50% missing information. However, using higher numbers of imputed data sets did not produce different results. Thus, I concluded to create ten imputed data sets for SEM analyses.

Variable	Without using multiple imputations β	SE	Using multiple imputations β	SE
Mentoring resource from PhD advisor only: *job-searching-related*				
Help on job searching				
Made phone calls for job search	0.42***	0.07	0.46***	0.06
Wrote recommendation letter(s)	0.63***	0.06	0.66***	0.05
Defended your career choices with colleagues	0.64***	0.05	0.64***	0.05
Gave advice about how to negotiate	0.75***	0.05	0.76***	0.04
Seeking advice on job searching – RI position				
Postdoctoral position	0.59***	0.05	0.59***	0.04
Research-intensive position	0.87***	0.04	0.86***	0.04
More competitive position than you were interested in	0.69***	0.05	0.67***	0.04
Seeking advice on job searching – TI position				
Teaching-intensive position	0.83***	0.10	0.89***	0.09
Non-academic position	0.60***	0.08	0.57***	0.07
Less competitive position than you were interested in	0.31**	0.10	0.33***	0.08
Mentoring resource from PhD advisors and postdoctoral supervisors: *non-job-searching-related*				
Research collaboration with PhD advisor				
Research grant proposal	0.95***	0.04	0.91***	0.04
Teaching or curricular grant proposal	0.74***	0.05	0.79***	0.05
Published one or more articles together	0.75***	0.04	0.74***	0.04
Help on career development from PhD advisor				
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	0.77***	0.03	0.76***	0.03
Invited you to join a teaching or research grant proposal team	0.71***	0.03	0.74***	0.03
Introduced you to potential research collaborators	0.72***	0.04	0.73***	0.03
Recommended you as an invited speaker/panel member	0.65***	0.04	0.66***	0.03
Provided you with research or other funding	0.59***	0.04	0.62***	0.03
Seeking advice on research from PhD advisor				
Grant getting	0.90***	0.02	0.89***	0.02
Publishing	0.91***	0.02	0.89***	0.02
Seeking advice on faculty workload within the department or university from PhD advisor				
Departmental politics	0.94***	0.02	0.94***	0.02
Student related issues	0.92***	0.02	0.93***	0.02
Interactions with colleagues	0.90***	0.02	0.90***	0.02
Seeking advice on workload outside the department or university from PhD advisor				
Collaborating with industry or government	0.72***	0.06	0.73***	0.05
Work/family balance	0.68***	0.06	0.69***	0.05

Note: †$p < .1$. *$p < .05$. **$p < .01$. ***$p < .001$.

5.4.1.2. SEM model predicting academic STEM scientists' early stage career advancement outcome and goodness-of-fit

Table 16 presents the empirical results of SEM testing gender, mentoring resource, and gender homophily in mentoring dyads on STEM female faculty members' time to obtain the first tenure-track position among the PhD only group. SEM analyses without and with using the multiple imputation techniques are reported. Using imputed data yields a sample size of 1,561 while the sample size is 1,146 when using the non-imputed data sets. Findings from SEM analyses using all available cases and using imputed data sets are quite consistent. Figure 9 presents a visual model of the significant paths in the analysis without using multiple imputations. Figure 10 presents significant paths in the analysis using multiple imputations.

Hypothesis 1, which contends that female junior scientists will report slower early stage career advancement than male counterparts, is not supported by the model either with or without using multiple imputation.

SEM analysis without using multiple imputations partially supports Hypothesis 2-1 that posits the relationship between mentoring resources from PhD advisors and STEM faculty members' career advancement outcomes. Among eight types of mentoring resources, STEM faculty members' research collaboration with their PhD advisors is found to decrease the time to obtain the first tenure-track position (Non-imputed model: $\beta=-0.31$, $p<0.05$). The relationship is not significant in the imputed model.

Hypothesis 3-1, which asserts that female junior scientists will report fewer mentoring resources reception from PhD advisors than male junior scientists, is partially supported by both non-imputation and imputation models. In particular, seven out of eight mentoring resources from PhD advisors are found to be significant. Female junior scientists receive less help during their first faculty job search (Non-imputed & imputed model: β=-0.29, $p<0.01$) and less mentoring resource as a form of seeking advice on searching teaching-intensive positions (Non-imputed model: β=-0.21, $p<0.10$; imputed model: β=-0.26, $p<0.05$) from their PhD advisors. When it comes to the non-job-searching-related mentoring from PhD advisors, female STEM scientists receive all five of them less than their male counterparts. They receive less help on career development (Non-imputed model: β=-0.23, $p<0.05$; imputed model: β=-0.25, $p<0.01$), do less research collaboration (Non-imputed model: β=-0.42, $p<0.01$; imputed model: β=-0.32, $p<0.10$), seek advice on research less (Non-imputed model: β=-0.27, $p<0.05$; imputed model: β=-0.28, $p<0.10$), seek advice on faculty work within the department or university less (Imputed model: β=-0.19, $p<0.10$), and seek advice on workload outside the department or university less (Non-imputed model: β=-0.81, $p<0.001$; imputed model: β=-0.26, $p<0.05$).

Both non-imputed and imputed model support Hypothesis 4-1 depicting that a greater proportion of female junior scientists, as compared to male scientists, will report gender homophily in the relationship with PhD advisors (Non-imputed model: β=0.59, $p<0.001$; imputed model: β=0.51, $p<0.001$).

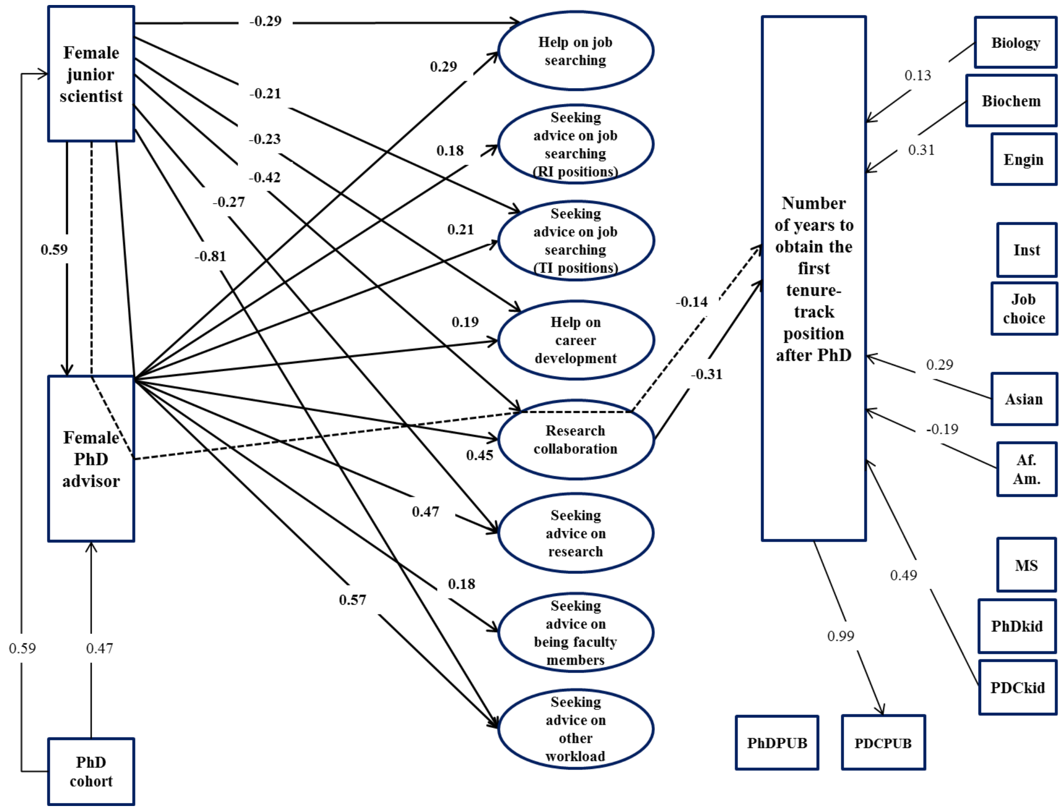

Figure 9. Visual Model of Significant Model Results Predicting STEM Faculty's Time to Obtain the First Tenure-track Position among Those Who Got a Tenure-track Job without Postdoctoral Training – No Data Imputation

Note 1: Dotted lines and arrows indicate indirect effects.

Note 2: **PhDPUB**: Total number of peer-reviewed journal articles published during and before PhD, **PDCPUB**: Total number of peer-reviewed journal articles published during postdoctoral period, **Biochem**: Biochemistry, **Engin**: Civil Engineering, **Inst**.: Current institution type, **PhDkid**: Having children during PhD, **PDCkid**: Having children during postdoctoral training, **MS**: Marital status, **Jobchoice**: Preferred career choice as finishing PhD

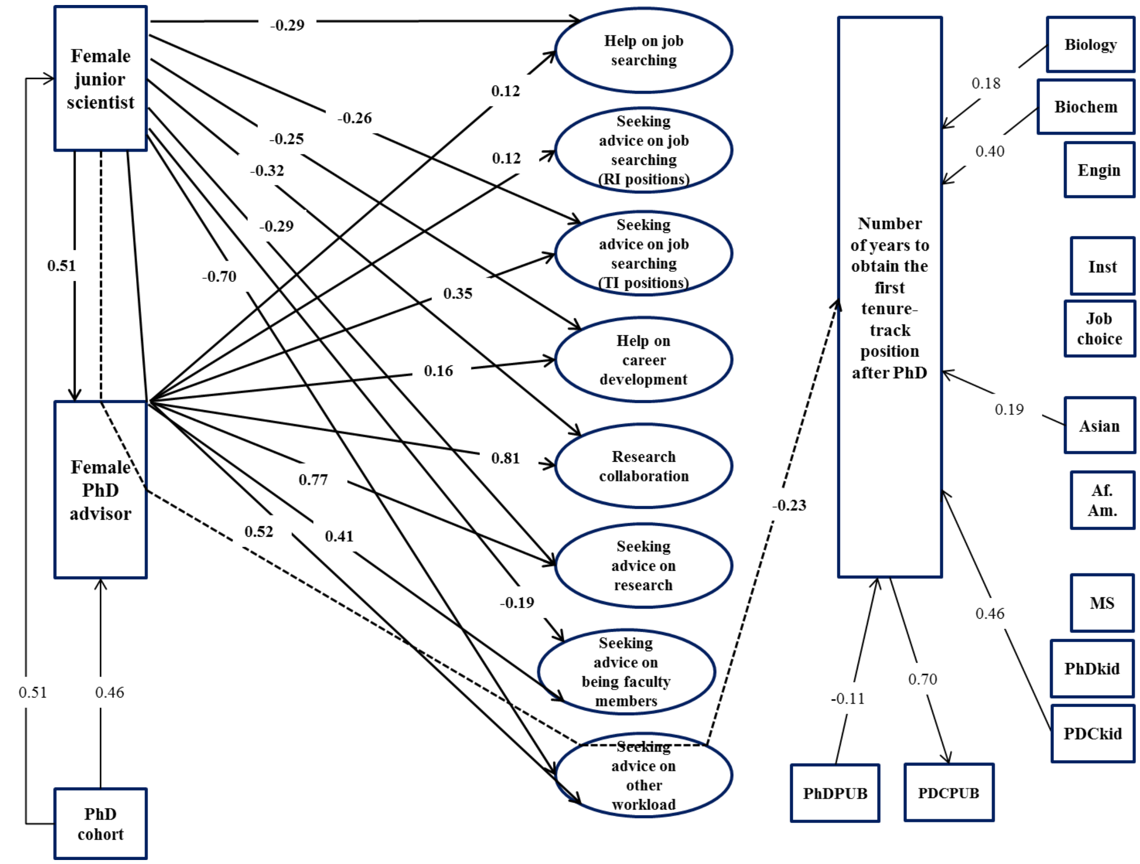

Figure 10. Visual Model of Significant Model Results Predicting STEM Faculty's Time to Obtain the First Tenure-track Position among Those Who Got a Tenure-track Job without Postdoctoral Training – Using Multiple Imputations

Note 1: Dotted lines and arrows indicate indirect effects.

Note 2: **PhDPUB**: Total number of peer-reviewed journal articles published during and before PhD, **PDCPUB**: Total number of peer-reviewed journal articles published during postdoctoral period, **Biochem**: Biochemistry, **Engin**: Civil Engineering, **Inst**.: Current institution type, **PhDkid**: Having children during PhD, **PDCkid**: Having children during postdoctoral training, **MS**: Marital status, **Jobchoice**: Preferred career choice as finishing PhD

Both non-imputed and imputed model support Hypothesis 5-1 that expects that female scientists who had the same-gender PhD advisors will report greater mentoring resource reception from the advisors through gender homophily in the mentoring relationship. SEM results show that female junior scientists receive more of all eight mentoring resources from female PhD advisors than those who had male advisors of mentoring dyads: help on job searching (Non-imputed model: β=0.29, p<0.001; imputed model: β=0.12, p<0.01), seeking advice on searching research-intensive position (Non-imputed model: β=0.18, p<0.001; imputed model: β=0.13, p<0.05), seeking advice on searching teaching-intensive position (Non-imputed model: β=0.21, p<0.001; imputed model: β=0.35, p<0.10), help on career development (Non-imputed model: β=0.19, p<0.001.; imputed model: β=0.16, p<0.01), research collaboration (Non-imputed model: β=0.45, p<0.001; imputed model: β=0.81, p<0.01), seeking advice on research (Non-imputed model: β=0.47, p<0.001; imputed model: β=0.77, p<0.01), seeking advice on faculty work within the department (Non-imputed model: β=0.18, p<0.001; imputed model: β=0.41, p<0.01), seeking advice on workload outside the department (Non-imputed model: β=0.57, p<0.001; imputed model: β=0.52, p<0.01).

SEM results for Hypotheses 3 through 5 yield an important story in this model. Female junior scientists receive the less mentoring resources from PhD advisors as compared to their male colleagues. However, they can receive more mentoring resources when they have female PhD advisors.

Hypothesis 6-1, expecting that female scientists who had the same-gender PhD advisors will report enhanced early stage career advancement through the mentoring resource provision from the advisors, is partially supported by both imputed and non-imputed models. The non-imputed model shows that female junior scientists who have female PhD advisors do research collaboration more with their PhD advisors, which leads to shorter time to obtain the first tenure-track positions (Non-imputed model: β=-0.14, $p<0.10$). The imputed model shows that female junior scientists who have female PhD advisors seek more advice on work-family balance from their PhD advisors, which leads to shorter time to obtain the first tenure-track positions (Non-imputed model: β=-0.23, $p<0.10$).

Table 16.

Standardized Results of Structural Model Predicting STEM Faculty's Time to Obtain the First Tenure-track Position Among Those Who Got a Tenure-track Job Without Postdoctoral Training

		Without using multiple imputation			Using multiple imputation		
	Path	β	SE	H. Support	β	SE	H. Support
H1	**Female mentee → TTJ**	0.07	0.12	**NS**	0.03	0.10	**NS**
H2-1	**ADV mentoring → TTJ**			**PS**			**NS**
	Help on job searching	-0.21	0.14		-0.15	0.12	
	Seeking advice on searching RI position	-0.14	0.19		0.02	0.14	
	Seeking advice on searching TI position	0.16	0.13		-0.01	0.10	
	Help on career development	0.55	0.36		0.41	0.31	
	Research collaboration	-0.31^{*}	0.16		-0.11	0.13	
	Seeking advice on research	-0.18	0.30		-0.37	0.35	
	Seeking advice on workload in the department	-0.09	0.28		0.17	0.22	
	Seeking advice on workload outside the department	0.14	0.15		-0.02	0.14	
H3-1	**Female mentee → ADV mentoring**			**PS**			**PS**
	Help on job searching	-0.29^{**}	0.11		-0.29^{**}	0.11	
	Seeking advice on searching RI position	-0.02	0.10		-0.12	0.10	
	Seeking advice on searching TI position	$-0.21^{\dagger}$	0.12		-0.26^{*}	0.11	
	Help on career development	-0.23^{*}	0.09		-0.25^{**}	0.08	
	Research collaboration	-0.42^{**}	0.14		$-0.32^{\dagger}$	0.17	
	Seeking advice on research	-0.27^{*}	0.13		$-0.29^{\dagger}$	0.16	
	Seeking advice on workload in the department	-0.17	0.12		$-0.19^{\dagger}$	0.20	
	Seeking advice on workload outside the department	-0.81^{***}	0.18		-0.26^{*}	0.11	
H4-1	**Female mentee → Female ADV**	0.59^{***}	0.10	**S**	0.51^{***}	0.16	**S**
H5-1	**Female mentee → Female ADV → ADV mentoring**			**S**			**S**
	Help on job searching	0.29^{***}	0.06		0.12^{**}	0.05	

	Seeking advice on searching RI position	0.18^{***}	0.04		0.13^{*}	0.05	
	Seeking advice on searching TI position	0.21^{***}	0.06		$0.35^{\dagger}$	0.18	
	Help on career development	0.19^{***}	0.05		0.16^{**}	0.05	
	Research collaboration	0.45^{***}	0.09		0.81^{**}	0.29	
	Seeking advice on research	0.47^{***}	0.10		0.77^{**}	0.28	
	Seeking advice on workload in the department	0.18^{***}	0.05		0.41^{**}	0.16	
	Seeking advice on workload outside the department	0.57^{***}	0.12		0.52^{**}	0.17	
H6-1	**Female mentee → Female ADV → ADV mentoring → TTJ**			**PS**			**PS**
	Help on job searching	-0.06	0.42		-0.04	0.04	
	Seeking advice on searching RI position	-0.03	0.04		0.00	0.03	
	Seeking advice on searching TI position	0.03	0.03		0.00	0.02	
	Help on career development	0.10	0.07		0.07	0.06	
	Research collaboration	$-0.14^{\dagger}$	0.78		-0.05	0.06	
	Seeking advice on research	-0.09	0.14		-0.17	0.18	
	Seeking advice on workload in the department	-0.02	0.05		0.03	0.04	
	Seeking advice on workload outside the department	0.08	0.09		$-0.23^{\dagger}$	0.14	
	N=	1,146			1,561		
	Chi-square	p<0.001			p<0.001		
	CFI	0.921			0.916		
	RMSEA	0.034			0.034		

Note: H1 to H6=Hypotheses 1 to 6; TTJ=Time to obtain the first tenure-track position; ADV mentoring=Mentoring resource from PhD advisors; H. Support= Whether SEM analyses support hypothesis; S=Hypothesis is supported; PS=Partially supported; NS=Not supported.

†p < .1. *p < .05. **p < .01. ***p < .001.

5.4.1.3. Additional findings in SEM model

Among the explanatory variables that are included in the model without being hypothesized, SEM findings show several significant direct and indirect paths. Several control variables have significant effects on STEM faculty's career advancement outcome. Findings of both non-imputed and imputed models support that it takes longer to get a tenure-track job for female STEM faculty members who have children during the postdoctoral period (Non-imputed model: β=0.49, p<0.001; imputed model: β=0.46, p<0.001), who are in STEM discipline of Biology (Non-imputed model: β=0.13, p<0.001;

imputed model: $\beta=0.12$, $p<0.001$) and Biochemistry (Non-imputed model: $\beta=0.31$, $p<0.05$; imputed model: $\beta=0.40$, $p<0.001$) in the PhD only group. Race also has significant impacts. With White as a reference group in the non-imputed model, it takes less time for African American (Non-imputed model: $\beta=-0.19$, $p<0.10$) whereas it takes longer for Asian STEM faculty members to get the first tenure-track positions (Non-imputed model: $\beta=0.29$, $p<0.001$). When the multiple imputation techniques are used, however, the race effects of being Asian remain significant (Imputed model: $\beta=0.19$, $p<0.01$) while the effects of being African American lose significance.

In the SEM analysis using multiple imputations, it is found that two more control variables have significant effects on STEM faculty career advancement outcomes. Greater numbers of peer-reviewed journal articles published during and before PhD leads shorter time to obtain the first tenure-track position (imputed model: $\beta=-0.11$, $p<0.01$). Also, it takes longer for STEM faculty members who are currently at research-intensive institutions to get their first tenure-track job (imputed model: $\beta=0.13$, $p<0.05$).

5.4.1.4. SEM model evaluation: Goodness-of-fit

To evaluate the model fit, the chi-square test, the comparative fit index (CFI), and the root mean square error of approximation (RMSEA) are examined. The three test results show that the model fit for both non-imputed and imputed models is good. For non-imputed model, Chi-square value is significant at a 0.001 threshold, CFI value is 0.921, and RMSEA value is 0.034, all of which indicate that both models with and without using imputed data sets fit the data well. Model fit for SEM analysis using multiple imputations is good as well. Chi-square value is significant at a 0.001 threshold, CFI value is 0.916, and RMSEA value is 0.034.

5.4.2. SEM analyses among respondents who obtained tenure-track position without postdoctoral training – postdoc group

This section presents the findings of the SEM model of the postdoc group. The model tests combined relationship between gender, mentoring resource from PhD advisors and the most recent postdoctoral supervisors, and gender homophily in mentoring dyads on STEM faculty's time to obtain the first tenure-track position among those who completed postdoctoral training before obtaining tenure-track positions. When it comes to mentors and mentoring resources, both PhD advisors and postdoctoral supervisors are taken into consideration because STEM faculty members who completed postdoctoral training have both PhD advisors and postdoctoral supervisors as well as received mentoring resources from either or both of them.

5.4.2.1. Measurement model estimates of significance between observed variables and latent constructs: Mentoring resource from PhD advisors and postdoctoral supervisors

Table 17 presented below shows the measurement model estimates of the significance between latent constructs indicating mentoring resources and observable variables in the postdoc group model. The findings of estimates present that all observed variables have significant (p<0.001) positive relationships with the latent constructs of mentoring resources from PhD advisors and postdoctoral supervisors, indicating that the latent constructs well represent the theoretical constructs of the mentoring.

Table 17.

Measurement Model Estimates of Significance Between Observed Variance and Latent Constructs for the Postdoc Group

Variable	Without using multiple imputation		Using multiple imputation	
	β	SE	β	SE
Mentoring resource from PhD advisor only: *job-searching-related*				
Help on job searching				
Made phone calls for job search	0.52***	0.05	0.50***	0.05
Wrote recommendation letter(s)	0.63***	0.05	0.74***	0.04
Defended your career choices with colleagues	0.58***	0.05	0.56***	0.04
Gave advice about how to negotiate	0.70***	0.04	0.69***	0.03
Seeking advice on job searching – RI position				
Postdoctoral position	0.59***	0.04	0.62***	0.04
Research-intensive position	0.79***	0.04	0.76***	0.04
More competitive position than you were interested in	0.55***	0.05	0.53***	0.05
Seeking advice on job searching – TI position				
Teaching-intensive position	0.99***	0.12	0.97***	0.11
Non-academic position	0.51***	0.08	0.56***	0.07
Less competitive position than you were interested in	0.38***	0.09	0.38***	0.08
Mentoring resource from PhD advisors and postdoctoral supervisors: *non-job-searching-related*				
Research collaboration with PhD advisor				
Research grant proposal	0.76***	0.04	0.80***	0.04
Teaching or curricular grant proposal	0.75***	0.05	0.70***	0.06
Published one or more articles together	0.58***	0.03	0.63***	0.04
Research collaboration with postdoctoral supervisor				
Research grant proposal	0.90***	0.03	0.88***	0.03
Teaching or curricular grant proposal	0.50***	0.03	0.54***	0.04
Published one or more articles together	0.76***	0.03	0.77***	0.03
Help on career development from PhD advisor				
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	0.67***	0.03	0.70***	0.03
Invited you to join a teaching or research grant proposal team	0.78***	0.02	0.81***	0.02
Introduced you to potential research collaborators	0.80***	0.03	0.78***	0.03
Recommended you as an invited speaker/panel member	0.65***	0.03	0.68***	0.03
Provided you with research or other funding	0.56***	0.03	0.61***	0.03
Help on career development from postdoctoral supervisor				
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	0.71***	0.03	0.72***	0.02
Invited you to join a teaching or research grant proposal team	0.82***	0.02	0.84***	0.02
Introduced you to potential research collaborators	0.71***	0.03	0.72***	0.03
Recommended you as an invited speaker/panel member	0.69***	0.03	0.72***	0.02
Provided you with research or other funding	0.57***	0.03	0.63***	0.03
Seeking advice on research from PhD advisor				
Grant getting	0.92***	0.02	0.92***	0.02
Publishing	0.90***	0.02	0.90***	0.02
Seeking advice on research from postdoctoral supervisor				

Grant getting	0.93***	0.01	0.94***	0.01
Publishing	0.90***	0.02	0.91***	0.01
Seeking advice on faculty workload within the department or university from PhD advisor				
Departmental politics	0.87***	0.02	0.88***	0.02
Student related issues	0.90***	0.02	0.91***	0.02
Interactions with colleagues	0.90***	0.02	0.92***	0.02
Seeking advice on faculty workload within the department or university from postdoctoral supervisor				
Departmental politics	0.83***	0.02	0.85***	0.02
Student related issues	0.91***	0.03	0.91***	0.02
Interactions with colleagues	0.89***	0.02	0.91***	0.02
Seeking advice on workload outside the department or university from PhD advisor				
Collaborating with industry or government	0.69***	0.06	0.69***	0.05
Work/family balance	0.73***	0.05	0.74***	0.04
Seeking advice on workload outside the department or university postdoctoral supervisor				
Collaborating with industry or government	0.74***	0.04	0.74***	0.04
Work/family balance	0.79***	0.04	0.80***	0.03

Note: †$p < .1$. *$p < .05$. **$p < .01$. ***$p < .001$.

5.4.2.2. SEM model predicting academic STEM scientists' early stage career advancement outcome

Table 18 shows the empirical results of SEM analyses testing gender, mentoring resource from PhD advisors and postdoctoral supervisors, and gender homophily in mentoring dyads on STEM faculty's time to obtain the first tenure-track position among those who completed postdoctoral training before obtaining tenure-track positions. Like in the PhD only group model, SEM analyses are conducted using the multiple imputation techniques and using all available cases without using imputed values. Using imputed data yields a sample size of 2,346 while the sample size is 1,907 when using the non-imputed data sets. As seen in Table 18, SEM results of significance and directions of relationships between latent factors from imputed and non-imputed model results are quite consistent. In Figure 11, a visual model of the significant paths in the analysis without using multiple imputations is presented. Figure 12 presents significant paths in the same model using imputed data sets.

In postdoc group model, SEM results show that Hypothesis 1, which expects that female junior scientists will report slower early stage career advancement than male counterparts, is not supported. Controlling for other variables, neither the non-imputed model nor the imputed model shows a significant gender difference in time to obtain the first tenure-track positions among those who completed postdoctoral training.

Both SEM analyses with and without using imputed data partially support Hypothesis 2-1, which posits positive effects of mentoring resources from PhD advisors on STEM faculty members' career advancement outcomes. SEM results show that one job-searching-related and two non-job-searching-related mentoring resources have significant positive effects on STEM faculty members' career advancement outcome. In particular, PhD advisors' help during junior scientists' first faculty job search decreases time to obtain the job (Non-imputed model: $\beta=-0.25$, $p<0.05$; imputed model: $\beta=-0.23$, $p<0.05$). As for non-job-searching-related mentoring resources, PhD advisors' help on career development (Non-imputed model: $\beta=-0.5$, $p<0.001$; imputed model: $\beta=-0.47$, $p<0.001$) and greater reported advice from PhD advisors on research more (Non-imputed model: $\beta=-0.39$, $p<0.01$; imputed model: $\beta=-0.39$, $p<0.01$) are found to decrease the time to obtain the first tenure-track position among STEM faculty members.

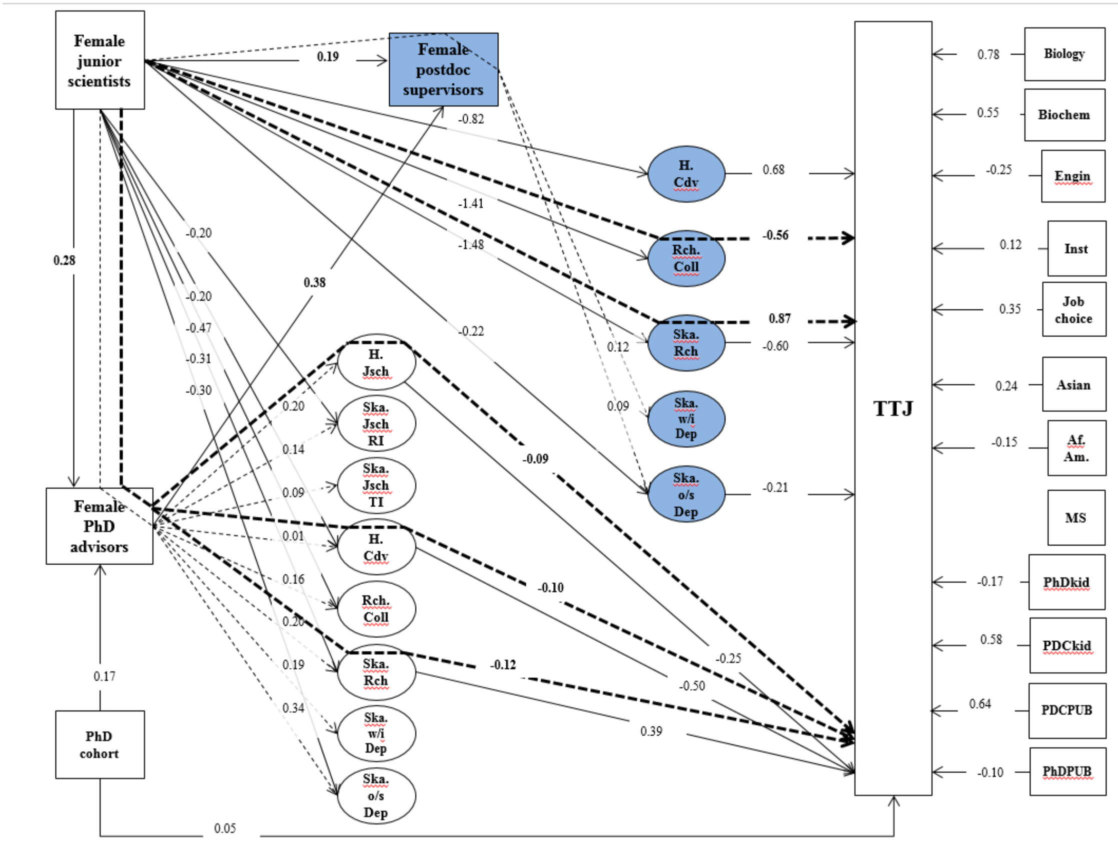

Figure 11. Visual Model of Significant Model Results Predicting STEM Faculty's Time to Obtain the First Tenure-track Position among Those Who Got a Tenure-track Job after Having Postdoctoral Training – No Data Imputation

Note 1: Dotted lines and arrows indicate indirect effects.

Note 2: **H.Jsch:** Help on job searching, **Ska.JschRI:** Seeking advice on job searching – RI position, **Ska.JschTI:** Seeking advice on job searching – TI position, **Rch.Coll:** Research collaboration with PhD advisor, **H.Cdv:** Help on career development from PhD , dvisor, **Ska.Rch:** Seeking advice on research from PhD advisor, **Ska.w/iDep:** Seeking advice on faculty workload within the department or university from PhD advisor, **Ska.o/sDep:** Seeking advice on workload outside the department or university from PhD advisor, **PhDPUB**: Total number of peer-reviewed journal articles published during and before PhD, **PDCPUB**: Total number of peer-reviewed journal articles published during postdoctoral period, **Biochem**: Biochemistry, **Engin**: Civil Engineering, **Inst**.: Current institution type, **PhDkid**: Having children during PhD, **PDCkid**: Having children during postdoctoral training, **MS**: Marital status, **Jobchoice**: Preferred career choice as finishing PhD

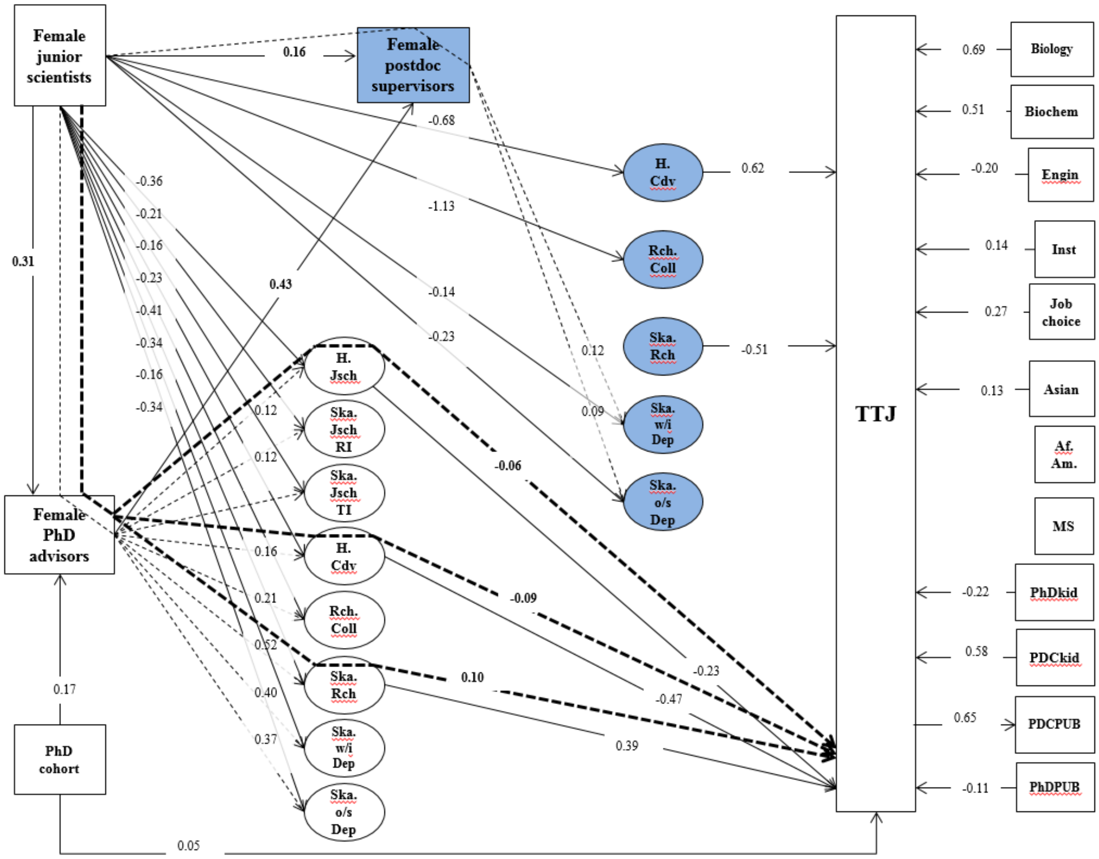

Figure 12. Visual Model of Significant Model Results Predicting STEM Faculty's Time to Obtain the First Tenure-track Position Among Those Who Got a Tenure-track Job after Having Postdoctoral Training – Using Multiple Imputation Technique

Note 1: Dotted lines and arrows indicate indirect effects.

Note 2: **H.Jsch:** Help on job searching, **Ska.JschRI:** Seeking advice on job searching – RI position, **Ska.JschTI:** Seeking advice on job searching – TI position, **Rch.Coll:** Research collaboration with PhD advisor, **H.Cdv:** Help on career development from PhD , dvisor, **Ska.Rch:** Seeking advice on research from PhD advisor, **Ska.w/iDep:** Seeking advice on faculty workload within the department or university from PhD advisor, **Ska.o/sDep:** Seeking advice on workload outside the department or university from PhD advisor, **PhDPUB**: Total number of peer-reviewed journal articles published during and before PhD, **PDCPUB**: Total number of peer-reviewed journal articles published during postdoctoral period, **Biochem**: Biochemistry, **Engin**: Civil Engineering, **Inst**.: Current institution type, **PhDkid**: Having children during PhD, **PDCkid**: Having children during postdoctoral training, **MS**: Marital status, **Jobchoice**: Preferred career choice as finishing PhD

Hypothesis 2-2, depicting that mentoring resources from postdoctoral supervisors will have positive impacts on STEM faculty members' career advancement outcomes is partially supported. For a latent construct indicating mentoring resources from postdoctoral supervisors, five observed variables of non-job-searching related are used. Among the five latent constructs, postdoctoral supervisors' help on junior scientists' career development (Non-imputed model: $\beta=0.68$, $p<0.001$; imputed model: $\beta=0.47$, $p<0.001$) and junior scientists' seeking advice from PhD advisors on research (Non-imputed model: $\beta=-0.39$, $p<0.01$; imputed model: $\beta=-0.39$, $p<0.01$) have significant impacts on the time to obtain the first tenure-track position among STEM faculty members. However, the direction of the relationship between postdoctoral supervisors' help on junior scientists' career development and time to get a job is opposite to that expected in Hypotheses 2-2.

Hypothesis 3-1, which expects that female junior scientists will report fewer mentoring resources received from PhD advisors, is partially supported by non-imputation model. The model using imputed data fully supports Hypothesis 3-1. Female STEM faculty members who completed postdoctoral training receive less of all eight types of mentoring resources than male counterparts. Female junior scientists receive less job-searching-related mentoring resource from PhD advisors. Female receive less help from their PhD advisors during their first faculty job search (Imputed model: $\beta=-0.36$, $p<0.001$), seek advice on searching research-intensive positions less (Non-imputed model: $\beta=-0.20$, $p<0.05$; imputed model: $\beta=-0.21$, $p<0.01$) as well as seek advice on searching teaching-intensive positions less than male (Imputed model: $\beta=-0.16$, $p<0.10$). SEM findings show that female junior scientists in the postdoc group receive less non-job-searching-related mentoring resource from PhD advisors. Females receive less help on career development (Non-imputed model: β=-0.20, $p<0.01$; imputed model: β=-0.23, $p<0.001$), collaborate less (Non-imputed model: β=-0.47, $p<0.001$; imputed model: β=-0.41, $p<0.001$), are less likely to seek advice on research (Non-imputed model: β=-0.31, $p<0.001$; imputed model: β=-0.34, $p<0.001$), faculty workload within the department or university (Imputed model: β=-0.16, $p<0.10$), and seek advice on faculty work outside the department or university less (Non-imputed model: β=-0.31, $p<0.05$; imputed model: β=-0.34, $p<0.01$) from their PhD advisors.

Hypothesis 3-2, which expects that female junior scientists will report fewer mentoring resources received from postdoctoral supervisors than male junior scientists, is partially supported by both non-imputation and imputed model. Female receive less help on career development from their postdoctoral supervisors (Non-imputed model: β=-0.82, $p<0.01$; imputed model: β=-0.68, $p<0.01$), less advice on research (Non-imputed model: β=-1.48, $p<0.05$), less advice on faculty work within the department or university (Imputed model: β=-0.14, $p<0.001$), and less advice on workload outside the department or university (Non-imputed model: β=-0.22, $p<0.10$; imputed model: β=-0.23, $p<0.01$). Also, female scientists collaborate less (Non-imputed model: β=-1.41, $p<0.01$; imputed model: β=-1.13, $p<0.001$) with their postdoctoral supervisors than their male colleagues.

Both non-imputed and imputed models support Hypothesis 4-1 and 4-2 depicting that a greater proportion of female junior scientists, as compared to male scientists, will report gender homophily in the relationship with PhD advisors (Non-imputed model: β=0.28, $p<0.001$; imputed model: β=0.31, $p<0.001$) and postdoctoral supervisors (Non-imputed model: β=0.19, $p<0.05$; imputed model: β=0.16, $p<0.10$).

Hypothesis 5-1, expecting that female scientists who had the same-gender PhD advisors will report greater mentoring resource reception from the advisors through gender homophily in the mentoring relationship, is fully supported by non-imputed model and partially supported by the model using imputed data sets. Except for one latent mentoring resource variable indicating STEM faculty's seeking advice on searching teaching-intensive position, female STEM faculty members receive more mentoring resources from female PhD advisors as compared to those who had male PhD advisors. In particular, from female PhD advisors, female junior scientists receive more help on job searching (Non-imputed model: $\beta=0.20$, $p<0.001$; imputed model: $\beta=0.12$, $p<0.001$), more advice on searching research-intensive position (Non-imputed model: $\beta=0.14$, $p<0.001$; imputed model: $\beta=0.12$, $p<0.001$), more advice on searching teaching-intensive position (Non-imputed model: $\beta=0.09$, $p<0.01$), more help on career development (Non-imputed model: $\beta=0.14$, $p<0.001$.; imputed model: $\beta=0.16$, $p<0.001$), more research collaboration (Non-imputed model: $\beta=0.16$, $p<0.001$; imputed model: $\beta=0.21$, $p<0.001$), more advice on research (Non-imputed model: $\beta=0.20$, $p<0.001$; imputed model: $\beta=0.52$, $p<0.001$), more advice on faculty work within the department (Non-imputed model: $\beta=0.19$, $p<0.001$; imputed model: $\beta=0.40$, $p<0.01$), and more advice on faculty workload outside the department (Non-imputed model: $\beta=0.34$, $p<0.001$; imputed model: $\beta=0.37$, $p<0.01$).

Hypothesis 5-2, which contends that female scientists who had same-gender postdoctoral supervisors will report receiving greater mentoring resources reception from their supervisors through gender homophily in the mentoring relationship, is partially supported by the non-imputed model as well as the imputed model. SEM analyses report that female junior scientists receive more advice on faculty work within the department (Non-imputed model: $\beta=0.12$, $p<0.05$; imputed model: $\beta=0.12$, $p<0.10$) and on faculty workload outside the department (Non-imputed model: $\beta=0.09$, $p<0.10$; imputed model: $\beta=0.12$, $p<0.10$) from female postdoctoral supervisors.

Hypothesis 6-1, expecting that female scientists who had the same-gender PhD advisors will report enhanced early stage career advancement through the mentoring resource provision from the advisors, is partially supported by non-imputed and imputed model. SEM analyses show that three indirect paths indicating gender effects on time to obtain the first tenure-track position through female PhD advisor and mentoring resources are significant. Firstly, that female junior scientists who receive help on job searching from female PhD advisors have a shorter time to obtain the first tenure-track positions (Non-imputed model: $\beta=-0.09$, $p<0.05$; imputed model: $\beta=-0.06$, $p<0.05$). The second indirect significant path in the model indicates that female junior scientists who receive more help on career development from female PhD advisors have a shorter time to obtain the first tenure-track positions (Non-imputed model: $\beta=-0.10$, $p<0.01$; imputed model: $\beta=-0.09$, $p<0.01$). Although the last indirect path shows significant effects, the direction of the effect is not in the expected direction. The last indirect path shows that female junior scientists who seek more advice on research from female PhD advisors have the longer time to obtain the first tenure-track positions (Non-imputed model: $\beta=0.12$, $p<0.05$; imputed model: $\beta=0.10$, $p<0.05$).

Hypothesis 6-2, expecting that female scientists who had the same-gender postdoctoral supervisors will report enhanced early stage career advancement due to mentoring resources from the supervisors, is partially supported by non-imputed model while it is not supported by the imputed model. The non-imputed model shows that female junior scientists who collaborate with their female postdoctoral supervisors (Non-imputed model: β=-0.56, p<0.05) have a shorter time to obtain the first tenure-track positions. However, despite doing research together, seeking more advice on research yields adverse career advancement outcome. Female junior scientists who seek advice from female postdoctoral supervisors on their research report longer time to obtain the first tenure-track positions (Non-imputed model: β=0.87, p<0.05) as compared to those who had male postdoctoral supervisors.

Hypotheses 6-1 and 6-2 that show that seeking advice from PhD advisors and postdoctoral supervisors is associated with longer time to obtain the first tenure-track positions for mentees. It may support previous studies' argument that lengthy dependence on a mentor may have negative influence on the mentees' career advancement outcomes (Richey et al., 1988). Kram's (1983) mentoring stage model emphasizes that a long-term mentoring relationships does not necessarily hinder mentees' scholarly progress only if mentors and mentees transform and continue their scholarly relationships as converting their relationships to the colleagueship between two independent scholars. In fact, other mentoring help and support which requires independent scholarly efforts on mentees' end such as research collaboration with mentors is associated with shorter time to obtain the first tenure-track position for mentees. Thus, it can be conclude that Hypotheses 6-1 and 6-2 support the current argument of mentoring studies that lengthy mentoring relationships that fail to move mentees onto new challenge to provide them opportunities to become independent scholars may have negative effects on mentees' career advancement outcomes.

Table 18.

Standardized Results of Structural Model Predicting STEM Faculty's Time to Obtain the First Tenure-track Position Among Those Who Got a Tenure-track Job After Completing Postdoctoral Training

		Without using multiple imputation			Using multiple imputation		
	Path	β	SE	H. Support	β	SE	H. Support
H1	**Female mentee → TTJ**	0.03	0.07	**NS**	0.01	0.06	**NS**
H2-1	**ADV mentoring → TTJ**			**PS**			**PS**
	Help on job searching	-0.25*	0.10		-0.23*	0.11	
	Seeking advice on searching RI position	0.09	0.09		0.12	0.10	
	Seeking advice on searching TI position	-0.05	0.06		-0.06	0.06	
	Help on career development	-0.50***	0.12		-0.47***	0.11	
	Research collaboration	0.05	0.07		0.08	0.10	
	Seeking advice on research	0.39**	0.13		0.39**	0.15	
	Seeking advice on workload in the department	-0.03	0.17		-0.06	0.16	
	Seeking advice on workload outside the department	0.01	0.08		-0.06	0.08	
H2-2	**SUP mentoring → TTJ**			**PS**			**PS**
	Help on career development	0.68***	0.13		0.62***	0.12	
	Research collaboration	0.00	0.08		-0.04	0.12	
	Seeking advice on research	-0.59***	0.13		-0.51***	0.15	
	Seeking advice on workload in the department	0.16	0.10		0.17	0.11	
	Seeking advice on workload outside the department	-0.12†	0.07		-0.11	0.07	
H3-1	**Female mentee → ADV mentoring**			**PS**			**S**
	Help on job searching	-0.37	0.09		-0.36***	0.08	
	Seeking advice on searching RI position	-0.20*	0.08		-0.21**	0.08	
	Seeking advice on searching TI position	-0.11	0.09		-0.16†	0.09	
	Help on career development	-0.20**	0.08		-0.23***	0.07	
	Research collaboration	-0.47***	0.10		-0.41***	0.09	
	Seeking advice on research	-0.31***	0.08		-0.34***	0.08	
	Seeking advice on workload in the department	-0.10	0.10		-0.16†	0.09	
	Seeking advice on workload outside the department	-0.30*	0.14		-0.34**	0.13	
H3-2	**Female mentee → SUP mentoring**			**PS**			**PS**
	Help on career development	-0.82**	0.32		-0.68**	0.22	
	Research collaboration	-1.41**	0.54		-1.13***	0.36	
	Seeking advice on research	-1.48*	0.58		-1.14	0.37	
	Seeking advice on workload in the department	-0.12	0.09		-0.14***	0.08	
	Seeking advice on workload outside the department	-0.22†	0.11		-0.23**	0.10	
H4-1	**Female mentee → Female ADV**	0.28***	0.07	**S**	0.31***	0.07	**S**
H4-2	**Female mentee → Female SUP**	0.19*	0.09	**S**	0.16†	0.08	**S**
H5-1	**Female mentee → Female ADV → ADV mentoring**			**S**			**PS**
	Help on job searching	0.20***	0.56		0.12***	0.03	
	Seeking advice on searching RI position	0.14***	0.04		0.12***	0.03	
	Seeking advice on searching TI position	0.09**	0.03		0.37	0.63	
	Help on career development	0.14***	0.04		0.16***	0.04	

	Research collaboration	0.16***	0.05		0.21***	0.06	
	Seeking advice on research	0.20***	0.04		0.52***	0.13	
	Seeking advice on workload in the department	0.19***	0.05		0.40***	0.10	
	Seeking advice on workload outside the department	0.34***	0.10		0.37***	0.01	
H5-2	**Female mentee → Female SUP → SUP mentoring**			**PS**			**PS**
	Help on career development	0.45	0.31		0.45	0.31	
	Research collaboration	0.78	0.54		0.78	0.54	
	Seeking advice on research	0.84	0.59		0.84	0.59	
	Seeking advice on workload in the department	0.12*	0.06		0.12†	0.71	
	Seeking advice on workload outside the department	0.09†	0.05		0.12†	0.70	
H6-1	**Female mentee → Female ADV → ADV mentoring → TTJ**			**PS**			**PS**
	Help on job searching	-0.09*	0.05		-0.06*	0.03	
	Seeking advice on searching RI position	-0.02	0.02		0.02	0.02	
	Seeking advice on searching TI position	0.01	0.00		-0.01	0.01	
	Help on career development	-0.10*	0.04		-0.09**	0.03	
	Research collaboration	-0.02	0.04		0.01	0.02	
	Seeking advice on research	0.12*	0.05		0.10*	0.04	
	Seeking advice on workload in the department	0.00	0.02		-0.02	0.04	
	Seeking advice on workload outside the department	0.00	0.02		-0.03	0.04	
H6-2	**Female mentee → Female SUP → SUP mentoring → TTJ**			**PS**			**NS**
	Help on career development	0.00	0.11		0.23	0.16	
	Research collaboration	-0.56*	0.25		-0.02	0.07	
	Seeking advice on research	0.87*	0.40		-0.33	0.25	
	Seeking advice on workload in the department	0.03	0.20		0.02	0.01	
	Seeking advice on workload outside the department	-0.02	0.02		-0.01	0.01	
	N=	1,907			2,346		
	Chi-square	*p*<0.001			*p*<0.001		
	CFI	0.902			0.910		
	RMSEA	0.031			0.031		

Note: H1 to H6=Hypotheses 1 to 6; TTJ=Time to obtain the first tenure-track position; ADV mentoring=Mentoring resource from PhD advisors; SUP mentoring=Mentoring resource from postdoctoral supervisors; H. Support= Whether SEM analyses support hypothesis; S=Hypothesis is supported; PS=Partially supported; NS=Not supported.

†$p < .1$. *$p < .05$. **$p < .01$. ***$p < .001$.

5.4.2.3. Additional findings in SEM model

In the postdoc group model, SEM findings also show several significant direct and indirect paths among variables that were not hypothesized. Important non-hypothesized paths that SEM analyses show significant indirect paths from junior scientists' gender to mentoring resource from postdoctoral supervisors through having female postdoctoral supervisors as well as female PhD advisors. As shown above, SEM results do not strongly support Hypothesis 6-2 that asserts that female scientists who had female postdoctoral supervisors will report receiving greater mentoring resources from the supervisors. However, female junior scientists receive more mentoring resource from postdoctoral supervisors if they had female PhD advisors. They also receive more help on career development (Non-imputed model: $\beta=0.26$, $p<0.001$), research collaboration (Non-imputed model: $\beta=0.45$, $p<0.001$), seeking advice on research (Non-imputed model: $\beta=0.49$, $p<0.001$), advice on faculty work within the department (Non-imputed model: $\beta=0.05$, $p<0.05$), and advice on faculty workload outside the department (Non-imputed model: $\beta=0.07$, $p<0.05$).

In addition, SEM analyses reveal that there are two indirect gender effects on receiving the more mentoring resource from postdoctoral supervisors among those who had female PhD advisors and female supervisors that have significant impacts on STEM faculty's career advancement outcomes. The directions of the two relationships are not consistent. Female junior scientists who had female PhD advisors and female postdoctoral supervisors receive more help on career development (Non-imputed model: $\beta=0.18$, $p<0.01$), which leads to longer time to obtain the first tenure-track position. However, female junior scientists who had female PhD advisors and female postdoctoral supervisors seek more advice on research (Non-imputed model: $\beta=-0.29$, $p<0.01$), which leads to shorter time to obtain the position.

Several control variables have positive effects on STEM faculty early stage career development outcomes. Among STEM faculty members who completed postdoctoral training before getting the first tenure-track position, having greater numbers of peer-reviewed journal articles published during and before PhD (Non-imputed model: $\beta=-0.10$, $p<0.05$; imputed model: $\beta=-0.11$, $p<0.01$), having children during their PhD programs (Non-imputed model: $\beta=-0.17$, $p<0.01$; imputed model: $\beta=-0.22$, $p<0.001$), being in STEM discipline of Civil Engineering (Non-imputed model: $\beta=-2.46$, $p<0.01$; imputed model: $\beta=-0.20$, $p<0.05$) reported shorter time to obtain the first tenure-track position. In line with the results for the PhD only group, race also has significant impacts in SEM analyses for the postdoc group. With White as a reference group, in the non-imputed model, it takes shorter for African Americans (Non-imputed model: $\beta=-0.15$, $p<0.10$) and longer for Asian STEM faculty members to get their first tenure-track positions (Non-imputed model: $\beta=0.24$, $p<0.001$). However, when imputed data sets are used, the race effects of being Asian remain significant (Imputed model: $\beta=0.13$, $p<0.01$) while the effects of being African American loses its significance.

Other control variables present negative effects on STEM faculty early stage career development outcomes. STEM faculty members who have children during the postdoctoral period (Non-imputed model & imputed model: $\beta=0.58$, $p<0.001$), who are currently in research-intensive institutions (Non-imputed model: $\beta=0.12$, $p<0.01$; imputed model: $\beta=0.14$, $p<0.01$), who are in younger PhD cohort (Non-imputed model & imputed model: $\beta=0.05$), whose preferred career choice was tenure-track faculty position in a teaching-intensive environment, industry or government, or non-academic position (Non-imputed model: $\beta=0.05$, $p<0.05$; imputed model: $\beta=0.27$, $p<0.001$), and who are in STEM disciplines of Biology (Non-imputed model: $\beta=0.78$, $p<0.001$; imputed model:

β=0.69, p<0.001) and Biochemistry (Non-imputed model: β=0.56, p<0.001; imputed model: β=0.51, p<0.001) take longer to obtain the first tenure-track position.

5.4.2.4. SEM model evaluation: Goodness-of-fit

To evaluate the model fit, the chi-square test, the comparative fit index (CFI), and the root mean square error of approximation (RMSEA) are examined. The three test results show that the model fit for both non-imputed and imputed models is good. For non-imputed model, Chi-square value is significant at a 0.001 threshold, CFI value is 0.902, and RMSEA value is 0.031, all of which indicate that both models with and without using imputed data sets fit the data well. Model fit for SEM analysis using multiple imputations is good as well. Chi-square value is significant at a 0.001 threshold, CFI value is 0.910, and RMSEA value is 0.031.

5.5. Results from structural equation modeling (SEM) predicting academic STEM scientists' early stage career advancement outcome: *samples who are at the assistant rank*

This part presents the findings of the SEM models using samples only comprised of respondents who are at the assistant ranks. As briefly mentioned in the previous section, it can enhance robustness of findings to perform additional analyses using samples those who are at the assistant rank. It is because mentoring resource variables indicating junior scientists' research collaboration experiences with their PhD advisors and postdoctoral supervisors and mentors' help regarding junior scientists' career development capture junior STEM faculty's recent relationships with their PhD advisors and postdoctoral supervisors. Given that mentoring refers to help and support from those who are more experienced to those who are perceived to be less experienced in the career field, it may be reasonable to expect that junior STEM faculty members who are at the assistant rank are more likely to maintain their relationships with their key career mentors, PhD advisors and postdoctoral supervisors, and receive help and support from them. The expectation is supported by the data that is used for this study. As compared to the respondents who are at associate and full professor ranks, those who are at the assistant ranks are more likely to collaborate research with their mentors and receive more help on career development from their mentors[6]. Thus, the additional models focusing on those who are at the assistant ranks capture direct and indirect impacts of mentoring resource provision on STEM scientists' early stage career advancement outcome in a more robust manner.

5.5.1. SEM analyses among respondents who obtained tenure-track position without postdoctoral training and are at assistant rank – PhD only group

This section presents the findings of the SEM model of the assistant professors in the PhD only group. The model tests combined relationship between gender, mentoring resource from PhD advisors, and gender homophily in mentoring dyads on STEM faculty's time to obtain the first tenure-track position among those who got a tenure-track job without postdoctoral training and currently hold assistant professorship.

[6] In the sample, assistant professors are more likely to collaborate research with their PhD advisors ($\beta=0.40$, $p<0.001$) and receive more help on career development from their PhD advisors ($\beta=0.09$, $p<0.05$) compared to associate or full professors. Data shows that assistant professors receive more mentoring resources from their postdoctoral supervisors compared to associate or full professors. They are more likely to collaborate research with their postdoctoral supervisors ($\beta=0.58$, $p<0.001$) and receive more help on career development from their postdoctoral supervisors ($\beta=0.14$, $p<0.01$).

5.5.1.1. Measurement model estimates of significance between observed variables and latent constructs: Mentoring resource from PhD advisors

Table 19 lists the measurement model estimates of the significance between latent constructs indicating mentoring resources from PhD advisors and observable variables in the model for assistant professors in the PhD only group. The findings of estimates show that all observed variables in the model with and without using the multiple imputation techniques have significant positive relationships with the latent constructs, indicating that the latent constructs represent the theoretical constructs of mentoring.

Table 19.

Measurement Model Estimates of Significance Between Observed Variance and Latent Constructs for the PhD Only Group – Assistant Professors Only Model

	Without using multiple imputation		Using multiple imputation	
Variable	β	SE	β	SE
Mentoring resource from PhD advisor only: *job-searching-related*				
Help on job searching				
Wrote recommendation letter(s)	0.28**	0.09	0.42***	0.09
Defended your career choices with colleagues	0.75***	0.11	0.80***	0.08
Gave advice about how to negotiate	0.59***	0.09	0.65***	0.07
Seeking advice on job searching – RI position				
Research-intensive position	0.55***	0.11	0.53***	0.11
More competitive position than you were interested in	0.74***	0.14	0.71***	0.16
Seeking advice on job searching – TI position				
Postdoctoral position	0.99***	0.17	0.81***	0.21
Teaching-intensive position	0.48**	0.18	0.43**	0.17
Mentoring resource from PhD advisors and postdoctoral supervisors: *non-job-searching-related*				
Research collaboration with PhD advisor				
Research grant proposal	0.73***	0.07	0.76***	0.06
Published one or more articles together	0.73***	0.07	0.76***	0.06
Help on career development from PhD advisor				
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	0.84***	0.05	0.83***	0.05
Invited you to join a teaching or research grant proposal team	0.77***	0.06	0.77***	0.05
Introduced you to potential research collaborators	0.59***	0.08	0.60***	0.07
Recommended you as an invited speaker/panel member	0.56***	0.07	0.59***	0.06
Provided you with research or other funding	0.60***	0.07	0.62***	0.06

Seeking advice on research from PhD advisor				
Grant getting	0.99**	0.35	0.98	0.88
Publishing	0.96**	0.33	0.96	0.85
Seeking advice on faculty workload within the department or university from PhD advisor				
Departmental politics	0.91***	0.05	0.95***	0.04
Student related issues	0.91***	0.04	0.89***	0.04
Interactions with colleagues	0.87***	0.05	0.85***	0.05
Seeking advice on workload outside the department or university from PhD advisor				
Collaborating with industry or government	0.65***	0.11	0.67***	0.10
Work/family balance	0.61***	0.10	0.57***	0.09

Note: As compared to the SEM models using the whole sample comprised of assistant, associate, and full professors, some mentoring resource variables are not used in this model due to the lack of responses (less than 10%) that prevents the model identification and causes poor variance, which in turn yield biased estimates.
†$p < .1$. *$p < .05$. **$p < .01$. ***$p < .001$.

5.5.1.2. SEM model predicting academic STEM scientists' early stage career advancement outcome

Table 20 presents the empirical results of SEM predicting academic STEM female assistant professors' time to obtain the first tenure-track position among the PhD only group. SEM analyses using all available cases and imputed data sets are reported. Using imputed data yields a sample size of 331 while the sample size is 232 when using all available cases in the data sets. Findings from SEM analyses using all available cases and using imputed data sets are consistent.

Table 20.

Standardized Results of Structural Model Predicting STEM Assistant Professors' Time to Obtain the First Tenure-track Position Among Those Who Got a Tenure-track Job Without Postdoctoral Training

		Without using multiple imputation			Using multiple imputation		
	Path	β	SE	H. Support	β	SE	H. Support
H1	**Female mentee → TTJ**	0.09	0.98	**NS**	-0.04	0.28	**NS**
H2-1	**ADV mentoring → TTJ**			**NS**			**NS**
	Help on job searching	0.33	0.56		0.29	0.39	

	Seeking advice on searching RI position	0.21	1.10		-0.07	0.29	
	Seeking advice on searching TI position	-0.53	0.42		-0.29	0.28	
	Help on career development	0.02	0.81		-0.10	0.70	
	Research collaboration	0.09	1.15		-0.18	0.33	
	Seeking advice on research	-0.59	2.04		-0.25	0.99	
	Seeking advice on workload in the department	0.17	0.40		0.33	0.27	
	Seeking advice on workload outside the department	0.28	0.78		0.15	0.33	
H3-1	**Female mentee → ADV mentoring**			**PS**			**PS**
	Help on job searching	0.85*	0.40		0.62*	0.28	
	Seeking advice on searching RI position	-0.39	0.28		-0.20	0.23	
	Seeking advice on searching TI position	0.35	0.22		0.16	0.21	
	Help on career development	-0.13	0.23		-0.02	0.20	
	Research collaboration	0.11	0.27		0.26	0.22	
	Seeking advice on research	0.07	0.20		0.12	0.20	
	Seeking advice on workload in the department	0.06	0.22		0.35	0.35	
	Seeking advice on workload outside the department	0.16	0.35		0.27	0.31	
H4-1	**Female mentee → Female ADV**	0.57**	0.22	**S**	0.54**	0.18	**S**
H5-1	**Female mentee → Female ADV → ADV mentoring**			**PS**			**NS**
	Help on job searching	-0.68*	0.31		-0.25*	0.11	
	Seeking advice on searching RI position	-0.21*	0.10		-0.13†	0.07	
	Seeking advice on searching TI position	-0.32*	0.15		-0.44	0.54	
	Help on career development	-0.35*	0.15		-0.51*	0.21	
	Research collaboration	-0.17†	0.10		-0.22*	0.11	
	Seeking advice on research	-0.27†	0.16		-2.06	5.12	
	Seeking advice on workload in the department	0.02	0.08		-0.48†	0.27	
	Seeking advice on workload outside the department	-0.39*	0.18		-0.53*	0.21	
H6-1	**Female mentee → Female ADV → ADV mentoring → TTJ**			**NS**			**NS**
	Help on job searching	-0.04	0.23		-1.46	12.39	
	Seeking advice on searching RI position	0.17	0.15		0.14	2.14	
	Seeking advice on searching TI position	-0.02	0.20		0.84	5.45	
	Help on career development	-0.02	0.20		0.34	3.28	
	Research collaboration	-0.01	0.28		0.35	3.73	
	Seeking advice on research	0.16	0.62		0.89	9.27	
	Seeking advice on workload in the department	0.00	0.01		-0.51	3.44	
	Seeking advice on workload outside the department	-0.11	0.30		-0.81	6.05	
	N=	232			331		
	Chi-square	$p<0.001$			$p<0.001$		
	CFI	0.905			0.898		
	RMSEA	0.036			0.044		

Note: H1 to H6=Hypotheses 1 to 6; TTJ=Time to obtain the first tenure-track position; ADV mentoring=Mentoring resource from PhD advisors; H. Support= Whether SEM analyses support hypothesis; S=Hypothesis is supported; PS=Partially supported; NS=Not supported.

†$p < .1$. *$p < .05$. **$p < .01$. ***$p < .001$.

As SEM analyses using the whole samples comprised of faculty members of all ranks, SEM analyses using only assistant professors do not support Hypothesis 1. Controlling for other variables, neither SEM model using all available cases nor the model using imputed data sets finds negative direct gender effects on junior scientists' early stage career advancement.

Hypothesis 2-1, which contends positive relationships between mentoring resources from PhD advisors and STEM faculty members' career advancement outcomes, is not supported by STEM analyses regardless of using or not using imputed data sets.

Hypothesis 3-1 that expects that female junior scientists will report fewer mentoring resources reception from PhD advisors than male junior scientists, is not partially supported by either non-imputation or imputation models. Although both imputed (β=0.85, p<0.05) and non-imputed SEM models (β=0.62, p<0.05) present that female junior scientists report that they receive more PhD advisor mentoring resources by receiving more help on searching their first jobs, the direction of the relationships are opposed to what Hypothesis 3-1 expects.

Both non-imputed and imputed model support Hypothesis 4-1 depicting that a greater proportion of female assistant professors in STEM fields, as compared to male assistant professors, will report gender homophily in the relationship with PhD advisors (Non-imputed model: β=0.57, p<0.071; imputed model: β=0.54, p<0.071).

Hypothesis 5-1, which contends that female scientists who had the same-gender PhD advisors will report greater mentoring resource reception from the advisors through gender homophily in the mentoring relationship, is not supported in the SEM models with assistant professors in the PhD only group. Seven out of eight mentoring resources from female PhD advisors are found to be significant, but the directions are opposed to what Hypothesis 5-1 expects. SEM results show that female junior scientists receive fewer mentoring resources from female PhD advisors than those who has male PhD advisors: help on job searching (Non-imputed model: β=-0.68, p<0.05; imputed model: β=-0.25, p<0.05), seeking advice on searching research-intensive position (Non-imputed model: β=-0.21, p<0.05; imputed model: β=-0.13, p<0.10), seeking advice on searching teaching-intensive position (Non-imputed model: β=-0.32, p<0.05), help on career development (Non-imputed model: β=-0.35, p<0.05; imputed model: β=-0.51, p<0.05), research collaboration (Non-imputed model: β=-0.17, p<0.10; imputed model: β=-0.22, p<0.05), seeking advice on research (Non-imputed model: β=-0.27, p<0.10), seeking advice on faculty work within the department (Imputed model: β=-0.48, p<0.10), seeking advice on faculty workload outside the department (Non-imputed model: β=-0.39, p<0.05; imputed model: β=-0.53, p<0.05).

Among assistant professors in the PhD only group, Hypothesis 6-1, expecting that female scientists who had the same-gender PhD advisors will report enhanced early stage career advancement through the mentoring resource provision from the advisors, is not supported by either imputed or non-imputed models.

SEM analyses using samples comprised of junior STEM scientists who are at the assistant rank without having postdoctoral training yield unexpected results for most hypothesized relationships between gender, mentoring resources, and their early stage career advancement outcomes. None of mentoring resource from PhD advisors is found to have significant direct (H2) or indirect effect (H6) on the career advancement outcomes among academic STEM scientists who are currently at assistant ranks. Except for receiving more help from PhD advisors when they search the first jobs, there is no gender difference in receiving job-searching-related mentoring resources from PhD advisors among male assistant professors in STEM (H3). As opposed to the Hypothesis 5 expects, female assistant professors reported that they receive fewer mentoring resources from female PhD advisors. Why do PhD advisor mentoring resources do not have influence on the career advancement outcomes among academic STEM scientists who are currently at assistant ranks? What are the possible reasons that STEM assistant professors did not need mentoring resources from their PhD advisors?

To address these questions, it is important to note that 63.5% (207 out of 326) of the current assistant professors in STEM fields in the PhD only group preferred non-research-intensive positions (e.g., teaching-intensive positions, positions in industry or government, or non-tenure-track academic position) as they were finishing their PhDs. Accordingly, the data shows that 63.8% (211 out of 331) of the sample currently has positions at non-research-intensive institutions. Thus, it can be concluded that the majority of the sample might not have needed mentoring resources or the mentoring effects might not have had strong impacts on the career advancement outcomes in academia. Although the SEM results are not statistically significant, female assistant professors in the PhD only group are more likely to seek advice on searching teaching-intensive positions and the mentoring resource is associated with shorter time to obtain the first tenure-track position.

As for the rest 36.5%, assistant professors in STEM fields in the PhD only group whose preferred career choices were research-intensive positions as they were finishing their PhDs, it can be concluded that they might not have been in a great need of mentors' help and support because they were already highly competitive and productive. In addition, mentoring resources that they received did not have significant impacts on their career advancement outcomes as compared to their individual competitiveness and productivity. The data, in fact, shows that the assistant professors in STEM fields in the PhD only group whose preferred career choices were research-intensive positions as they were finishing their PhDs published 3.2 journal articles during their PhD programs on average while those whose preferred career choices were non-research-intensive positions published 2.4 articles ($p<0.10$). Moreover, they published during their PhD programs as much as the assistant professors in STEM fields in the postdoc group whose preferred career choices were non-research-intensive positions as they were finishing their PhDs did (3.1 articles on average).

Figure 13 presents a visual model of the significant paths in the SEM analyses using the sample comprised of those who currently have assistant professorships in the PhD only model without using multiple imputations. Figure 14 presents significant paths in the analysis using multiple imputations.

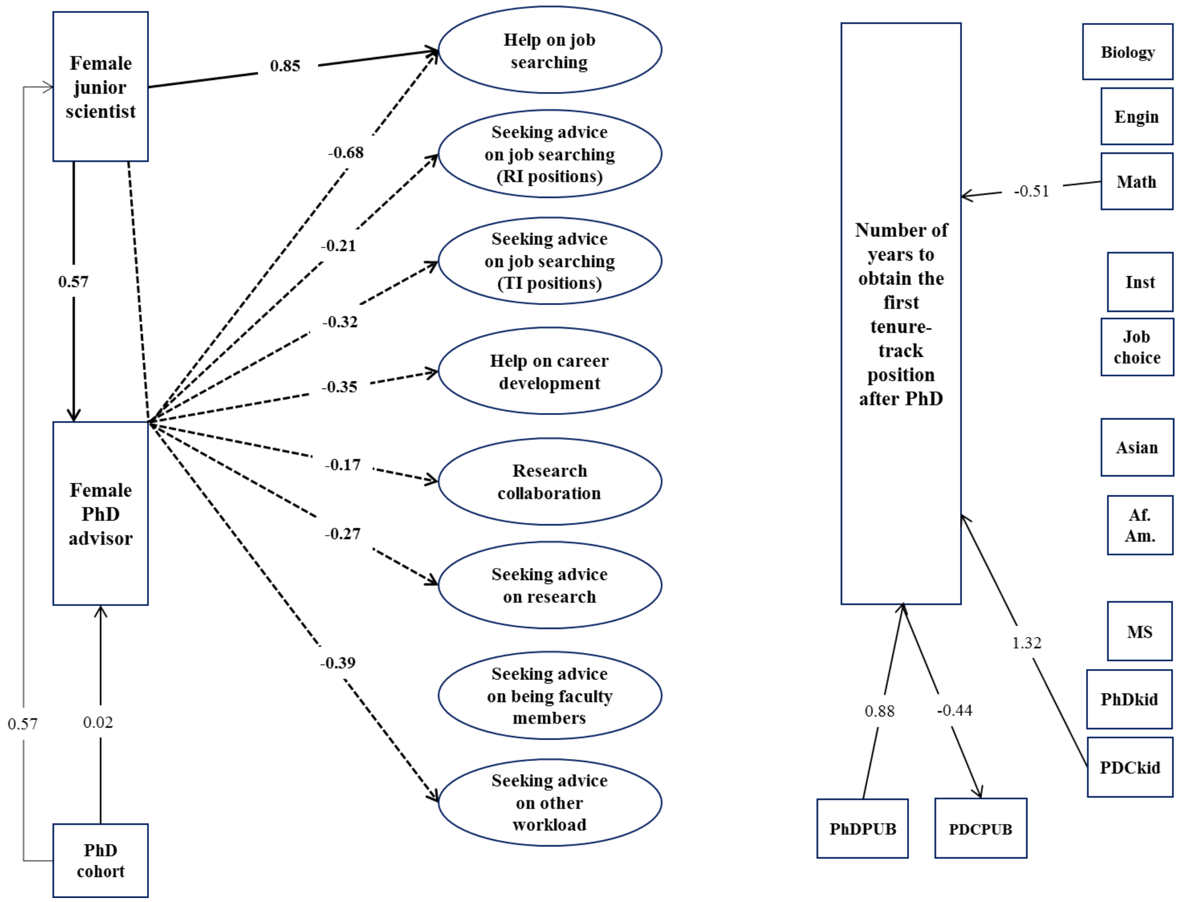

Figure 13. Visual Model of Significant Model Results Predicting STEM Faculty's Time to Obtain the First Tenure-track Position Among Those Who Are Currently at the Assistant Rank and Who Got a Tenure-track Job Without Postdoctoral Training – No Data Imputation

Note 1: Dotted lines and arrows indicate indirect effects.

Note 2: **PhDPUB**: Total number of peer-reviewed journal articles published during and before PhD, **PDCPUB**: Total number of peer-reviewed journal articles published during postdoctoral period, **Biochem**: Biochemistry, **Engin**: Civil Engineering, **Inst**.: Current institution type, **PhDkid**: Having children during PhD, **PDCkid**: Having children during postdoctoral training, **MS**: Marital status, **Jobchoice**: Preferred career choice as finishing PhD

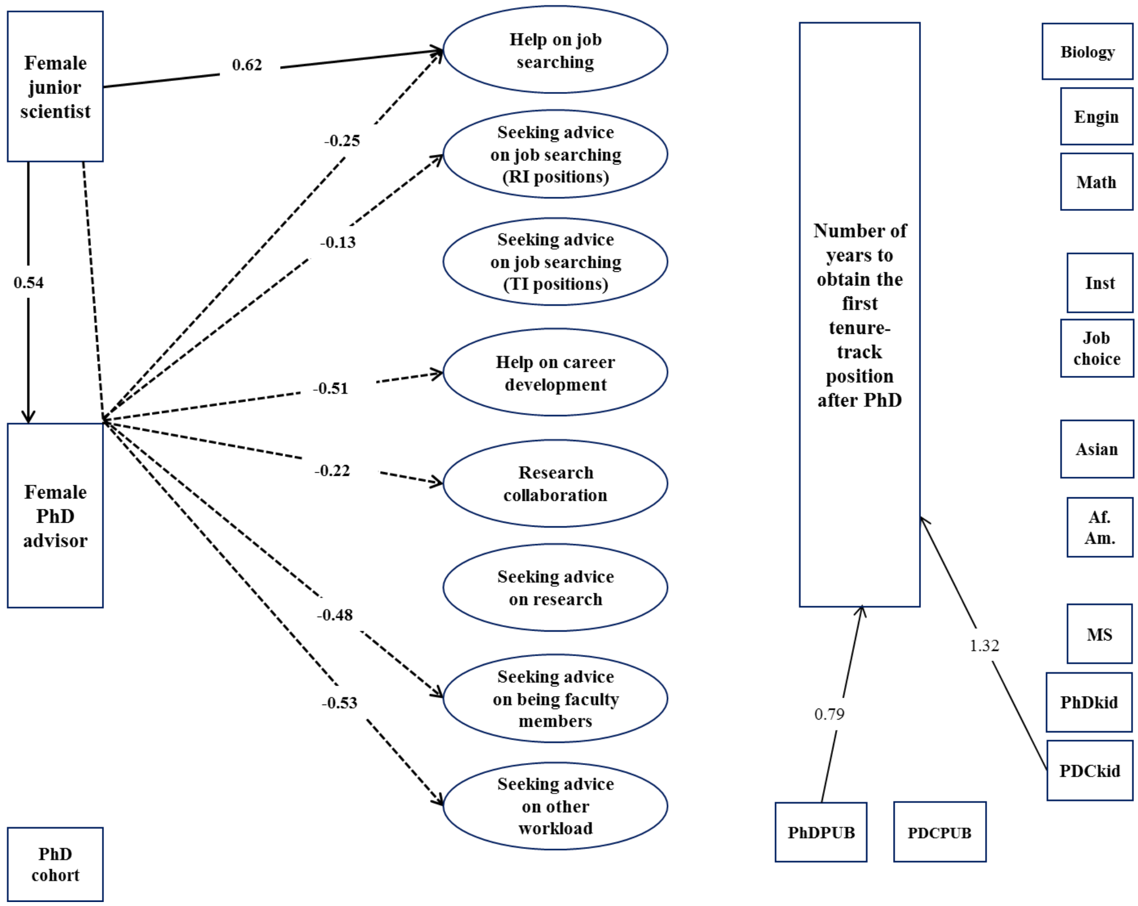

Figure 14. Visual Model of Significant Model Results Predicting STEM Faculty's Time to Obtain the First Tenure-track Position Among Those Who Are Currently at the Assistant Rank and Who Got a Tenure-track Job Without Postdoctoral Training – Using Multiple Imputation Technique

Note 1: Dotted lines and arrows indicate indirect effects.

Note 2: **PhDPUB**: Total number of peer-reviewed journal articles published during and before PhD, **PDCPUB**: Total number of peer-reviewed journal articles published during postdoctoral period, **Biochem**: Biochemistry, **Engin**: Civil Engineering, **Inst**.: Current institution type, **PhDkid**: Having children during PhD, **PDCkid**: Having children during postdoctoral training, **MS**: Marital status, **Jobchoice**: Preferred career choice as finishing PhD

5.5.1.3. Additional findings in SEM model

As in other SEM models analyzed in this study, several variables that are not hypothesized in the model using samples of assistant professors who did not completed the postdoctoral training before obtaining the first tenure-track positions have significant impacts on STEM faculty's career advancement outcomes. Findings of both non-imputed and imputed models support that it takes longer to get a tenure-track job for the current assistant professors who have more journal articles published during their PhD programs (Non-imputed model: $\beta=0.86$, $p<0.05$; imputed model: $\beta=0.79$, $p<0.001$) reported longer time to obtained the first tenure-track positions. As discussed in the previous section, it is because those who have more publications during their PhDs are more likely to aim to get a job at research-intensive institutions, which may lead them to spend more time to get a competitive positions. Also, those who had children during the postdoctoral period (Non-imputed model: $\beta=1.32$, $p<0.001$; imputed model: $\beta=1.32$, $p<0.001$) reported longer time to obtained the first tenure-track positions.

5.5.1.4. SEM model evaluation: Goodness-of-fit

The chi-square test, the comparative fit index (CFI), and the root mean square error of approximation (RMSEA) are examined. Model fit for SEM analysis without using multiple imputations is good. Chi-square value is significant at a 0.001 threshold, CFI value is 0.905, and RMSEA value is 0.036. For non-imputed model, Chi-square value is significant at a 0.001 threshold and RMSEA value is 0.044 that indicate that the model with and without using imputed data sets fit the data well. CFI value of 0.898 that indicates acceptable fit, which is very close to the good fit.

5.5.2. SEM analyses among respondents who obtained tenure-track position after having postdoctoral training and are at assistant rank – postdoc group

This section presents the findings of the SEM model using the sample of STEM assistant professors who completed postdoctoral training before obtaining tenure-track positions. The model tests combined relationship between gender, mentoring resource from PhD advisors and the most recent postdoctoral supervisors, and gender homophily in mentoring dyads on time to obtain the first tenure-track position among those who are currently at the assistant rank in the postdoc group.

5.5.2.1. Measurement model estimates of significance between observed variables and latent constructs: Mentoring resource from PhD advisors and postdoctoral supervisors

Table 21 presents the measurement model estimates of the significance between latent constructs indicating mentoring resources and observable variables in the postdoc group model among assistant professors. The findings of estimates present that all observed variables have significant (p<0.001) positive relationships with the latent constructs of mentoring resources from PhD advisors and postdoctoral supervisors, indicating that the latent constructs well represent the theoretical constructs of the mentoring.

Table 21.

Measurement Model Estimates of Significance Between Observed Variance and Latent Constructs for the Postdoc Group – Assistant Professors Only Model

Variable	Without using multiple imputation		Using multiple imputation	
	β	SE	β	SE
Mentoring resource from PhD advisor only: *job-searching-related*				

Help on job searching				
Wrote recommendation letter(s)	0.59***	0.08	0.69***	0.07
Defended your career choices with colleagues	0.45***	0.09	0.52***	0.08
Gave advice about how to negotiate	0.76***	0.09	0.75***	0.07
Seeking advice on job searching – RI position				
Research-intensive position	0.95***	0.16	0.89***	0.11
More competitive position than you were interested in	0.55***	0.10	0.58***	0.08
Seeking advice on job searching – TI position				
Postdoctoral position	0.77***	0.15	0.57***	0.09
Teaching-intensive position	0.39***	0.09	0.38***	0.08
Mentoring resource from PhD advisors and postdoctoral supervisors: *non-job-searching-related*				
Research collaboration with PhD advisor				
Research grant proposal	0.89***	0.10	0.86***	0.09
Published one or more articles together	0.52***	0.07	0.54***	0.07
Research collaboration with postdoctoral supervisor				
Research grant proposal	0.73***	0.06	0.75***	0.05
Published one or more articles together	0.63***	0.06	0.67***	0.05
Help on career development from PhD advisor				
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	0.58***	0.06	0.64***	0.05
Invited you to join a teaching or research grant proposal team	0.73***	0.05	0.75***	0.04
Introduced you to potential research collaborators	0.80***	0.07	0.79***	0.06
Recommended you as an invited speaker/panel member	0.67***	0.06	0.66***	0.06
Provided you with research or other funding	0.58***	0.06	0.64***	0.05
Help on career development from postdoctoral supervisor				
Reviewed your papers or proposals prior to submission (on which they were not a co-author)	0.73***	0.06	0.74***	0.04
Invited you to join a teaching or research grant proposal team	0.63***	0.06	0.79***	0.03
Introduced you to potential research collaborators	0.73***	0.06	0.74***	0.04
Recommended you as an invited speaker/panel member	0.63***	0.06	0.69***	0.04
Provided you with research or other funding	0.73***	0.06	0.67***	0.04
Seeking advice on research from postdoctoral supervisor				
Grant getting	0.91***	0.03	0.94***	0.02
Publishing	0.86***	0.03	0.88***	0.03
Seeking advice on faculty workload				
Departmental politics	0.80***	0.04	0.84***	0.04
Interactions with colleagues	0.88***	0.04	0.91***	0.04
Work/family balance	0.74***	0.05	0.78***	0.05

Note: As compared to the SEM models using the whole sample comprised of assistant, associate, and full professors, some mentoring resource variables are not used in this model due to the lack of responses (less than 10%) that prevents the model identification and causes poor variance, which in turn yield biased estimates.

Note: †$p < .1$. *$p < .05$. **$p < .01$. ***$p < .001$.

5.5.2.2. SEM model predicting academic STEM scientists' early stage career advancement outcome

Table 22 shows the empirical results of SEM analyses testing gender, mentoring resource from PhD advisors and postdoctoral supervisors, and gender homophily in mentoring dyads on STEM faculty's time to obtain the first tenure-track position among those who are currently at the assistant ranks and completed postdoctoral training before obtaining tenure-track positions. SEM analyses using imputed data yields a sample size of 681 and the sample size is 555 for the analyses using non-imputed data sets. As seen in Table 22 below, imputed and non-imputed model results provide consistent results in terms of supporting hypotheses. Figure 15 presents a visual model of the significant paths in the analysis without using multiple imputations is presented. Figure 16 presents significant paths in the same model using imputed data sets.

Table 22.

Standardized Results of Structural Model Predicting STEM Assistant Professors' Time to Obtain the First Tenure-track Position Among Those Who Got a Tenure-track Job After Completing Postdoctoral Training

		Without using multiple imputation			Using multiple imputation		
	Path	β	SE	H. Support	β	SE	H. Support
H1	**Female mentee → TTJ**	-0.02	0.07	**NS**	0.01	0.11	**NS**
H2-1	**ADV mentoring → TTJ**			**PS**			**PS**
	Help on job searching	0.05	0.10		-0.21	0.25	
	Seeking advice on searching RI position	-0.02	0.07		-0.28	0.35	
	Seeking advice on searching TI position	0.02	0.12		0.49	0.47	
	Help on career development	-0.25^{***}	0.09		-0.27^{**}	0.10	
	Research collaboration	0.02	0.07		0.03	0.08	
H2-2	**SUP mentoring → TTJ**			**PS**			**PS**
	Help on career development	0.42^{***}	0.09		0.47^{***}	0.12	
	Research collaboration	-0.12	0.08		-0.13	0.11	
	Seeking advice on workload in the department	-0.14	0.11		-0.18	0.13	
H3-1	**Female mentee → ADV mentoring**			**PS**			**PS**
	Help on job searching	-0.05	0.16		-0.14	0.15	

	Seeking advice on searching RI position	0.09	0.13		0.01	0.13	
	Seeking advice on searching TI position	0.03	0.16		-0.03	0.19	
	Help on career development	-0.46†	0.26		-0.38*	0.17	
	Research collaboration	-0.45*	0.18		-0.40*	0.17	
H3-2	**Female mentee → SUP mentoring**			**NS**			**NS**
	Help on career development	0.07	0.12		0.01	0.10	
	Research collaboration	-0.12	0.15		-0.06	0.13	
	Seeking advice on research	-0.01	0.13		0.00	0.11	
	Seeking advice on workload in the department	0.08	0.14		0.03	0.13	
H4-1	**Female mentee → Female ADV**	0.48***	0.13	**S**	0.46***	0.12	**S**
H4-2	**Female mentee → Female SUP**	0.07	0.15	**NS**	0.01*	0.14	**S**
H5-1	**Female mentee → Female ADV → ADV mentoring**			**PS**			**PS**
	Help on job searching	0.18*	0.07		0.21**	0.08	
	Seeking advice on searching RI position	0.01	0.04		0.06	0.09	
	Seeking advice on searching TI position	0.03	0.06		0.03	0.05	
	Help on career development	0.53*	0.24		0.32*	0.13	
	Research collaboration	0.15*	0.07		0.33*	0.13	
H5-2	**Female mentee → Female SUP → SUP mentoring**			**NS**			**NS**
	Help on career development	0.01	0.02		0.00	0.02	
	Research collaboration	0.01	0.03		0.00	0.03	
	Seeking advice on research	0.02	0.05		0.00	0.07	
	Seeking advice on workload in the department	0.02	0.04		0.00	0.13	
H6-1	**Female mentee → Female ADV → ADV mentoring → TTJ**			**PS**			**NS**
	Help on job searching	0.00	0.02		-0.08	0.09	
	Seeking advice on searching RI position	0.00	0.00		-0.01	0.02	
	Seeking advice on searching TI position	0.00	0.00		0.03	0.06	
	Help on career development	-0.13†	0.08		-0.10	0.09	
	Research collaboration	0.00	0.01		0.00	0.02	
H6-2	**Female mentee → Female SUP → SUP mentoring → TTJ**			**NS**			**NS**
	Help on career development	0.00	0.00		0.00	0.01	
	Research collaboration	0.00	0.00		0.00	0.01	
	Seeking advice on research	0.01	0.03		0.00	0.02	
	Seeking advice on workload in the department	-0.01	0.02		0.00	0.02	
	N=	555			681		
	Chi-square	*p*<0.001			*p*<0.001		
	CFI	0.926			0.923		
	RMSEA	0.028			0.032		

Note: H1 to H6=Hypotheses 1 to 6; TTJ=Time to obtain the first tenure-track position; ADV mentoring=Mentoring resource from PhD advisors; SUP mentoring=Mentoring resource from postdoctoral supervisors; H. Support= Whether SEM analyses support hypothesis; S=Hypothesis is supported; PS=Partially supported; NS=Not supported.

†*p* < .1. **p* < .05. ***p* < .01. ****p* < .001.

Among STEM assistant professors in postdoc group model, SEM results show that Hypothesis 1, predicting direct negative direct gender effects on the career advancement outcomes, is not supported.

Hypothesis 2-1, which posits positive effects of mentoring resources from PhD advisors on STEM faculty members' career advancement outcomes, is partially supported by SEM analyses with and without using imputed data. SEM results show that PhD advisor mentoring resource of providing help on career development (e.g., reviewing papers, inviting to join a grant proposal team, introducing to potential research collaborators, recommending as an invited speakers, or providing funding) decreases time to obtain the job for current assistant professors in STEM who are in the postdoc group (Non-imputed model: $\beta=-0.25$, $p<0.001$; imputed model: $\beta=-0.27$, $p<0.01$).

Hypothesis 2-2, depicting that mentoring resources from postdoctoral supervisors will have positive impacts on STEM faculty members' career advancement outcomes is partially supported in the model of the assistant professors in the postdoc groups. Among three latent constructs indicating mentoring resources from postdoctoral supervisors, postdoctoral supervisors' help on junior scientists' career development (Non-imputed model: $\beta=0.42$, $p<0.001$; imputed model: $\beta=0.47$, $p<0.001$) has significant impacts on the time to obtain the first tenure-track position among STEM faculty members. However, the direction of the relationship between postdoctoral supervisors' help on junior scientists' career development and time to get a job is opposite to that expected in Hypotheses 2-2. SEM results find that postdoctoral supervisors' help on junior scientists' research development increases STEM faculty members' time to obtain the first tenure-track position while PhD advisors' help on their research development decreases the time.

Hypothesis 3-1 that predicts of the negative direct gender effects on receiving mentoring resources from PhD advisors is partially supported by both imputation and non-imputation models. Female assistant professors in the postdoc group receive less help on career development (Non-imputed model: $\beta=-0.46$, $p<0.10$; imputed model: $\beta=-0.38$, $p<0.05$) from their PhD advisors. Female assistant professors in the postdoc group also collaborate less (Non-imputed model: $\beta=-0.45$, $p<0.05$; imputed model: $\beta=-0.40$, $p<0.05$) with their PhD advisors. SEM results show that Hypothesis 3-2, which expects that female junior scientists will report fewer mentoring resources received from postdoctoral supervisors than male junior scientists, is not supported.

Both models using non-imputed and imputed data sets support Hypothesis 4-1 depicting that female assistant professors in the postdoc group, as compared to their male counterparts, will report gender homophily in the relationship with PhD advisors (Non-imputed model: $\beta=0.48$, $p<0.001$; imputed model: $\beta=0.46$, $p<0.001$). Hypothesis 4-2 expecting the gender homophily in the mentoring relationships with postdoctoral supervisors among female junior scientists is supported by the imputed model only (Imputed model: $\beta=0.01$, $p<0.05$). However, it is important to note that there is significant relationship between female junior scientists and having female postdoctoral supervisors among those who had female PhD advisors (Non-imputed model: $\beta=0.23$, $p<0.05$).

Hypothesis 5-1 that expects that female scientists who had the same-gender PhD advisors will report greater mentoring resource reception from the advisors through gender homophily in the mentoring relationship, is partially supported by non-imputed model and imputed model. SEM analyses report that female assistant professors in the postdoc group receive more help on searching the first job (Non-imputed model: β=0.18, $p<0.05$; imputed model: β=0.21, $p<0.01$) and career development (Non-imputed model: β=0.53, $p<0.05$; imputed model: β=0.32, $p<0.05$) from their PhD advisors if they had female ones. It is also found that female assistant professors in the postdoc group collaborate with their female PhD advisors (Non-imputed model: β=0.15, $p<0.05$; imputed model: β=0.33, $p<0.05$) than those who had male PhD advisors. SEM analyses using the sample comprised of those who are assistant professors in STEM field in the postdoc group do not support indirect gender effects on mentoring resources through the same-gender mentoring dyads (H5-2).

SEM results show that Hypotheses 6-1, expecting that there are indirect gender effects on academic STEM scientists' time to obtain the first tenure-track positions through the same-gender mentoring dyads with PhD advisors, is partially supported in the model of the assistant professors in the postdoc group. Female assistant professors who receive help on career development from female PhD advisors report shorter time to obtain the first tenure-track positions (Non-imputed model: β=-0.13, $p<0.10$). Indirect gender effects on academic STEM scientists' time to obtain the first tenure-track positions through the same-gender mentoring dyads with postdoctoral supervisors (Hypothesis 6-2) is not supported.

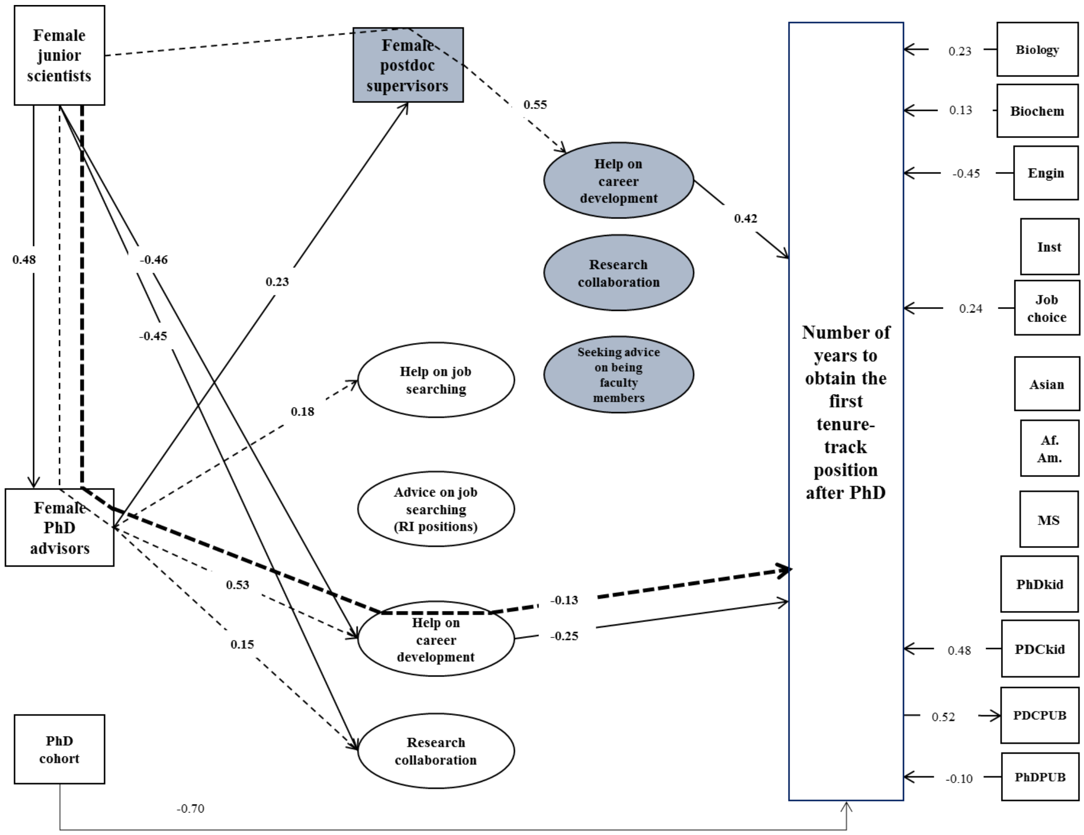

Figure 15. Visual Model of Significant Model Results Predicting STEM Faculty's Time to Obtain the First Tenure-track Position Among Those Who Are Currently at the Assistant Rank and Who Got a Tenure-track Job After Having Postdoctoral Training – No Data Imputation

Note 1: Dotted lines and arrows indicate indirect effects.

Note 2: **PhDPUB**: Total number of peer-reviewed journal articles published during and before PhD, **PDCPUB**: Total number of peer-reviewed journal articles published during postdoctoral period, **Biochem**: Biochemistry, **Engin**: Civil Engineering, **Inst**.: Current institution type, **PhDkid**: Having children during PhD, **PDCkid**: Having children during postdoctoral training, **MS**: Marital status, **Jobchoice**: Preferred career choice as finishing PhD

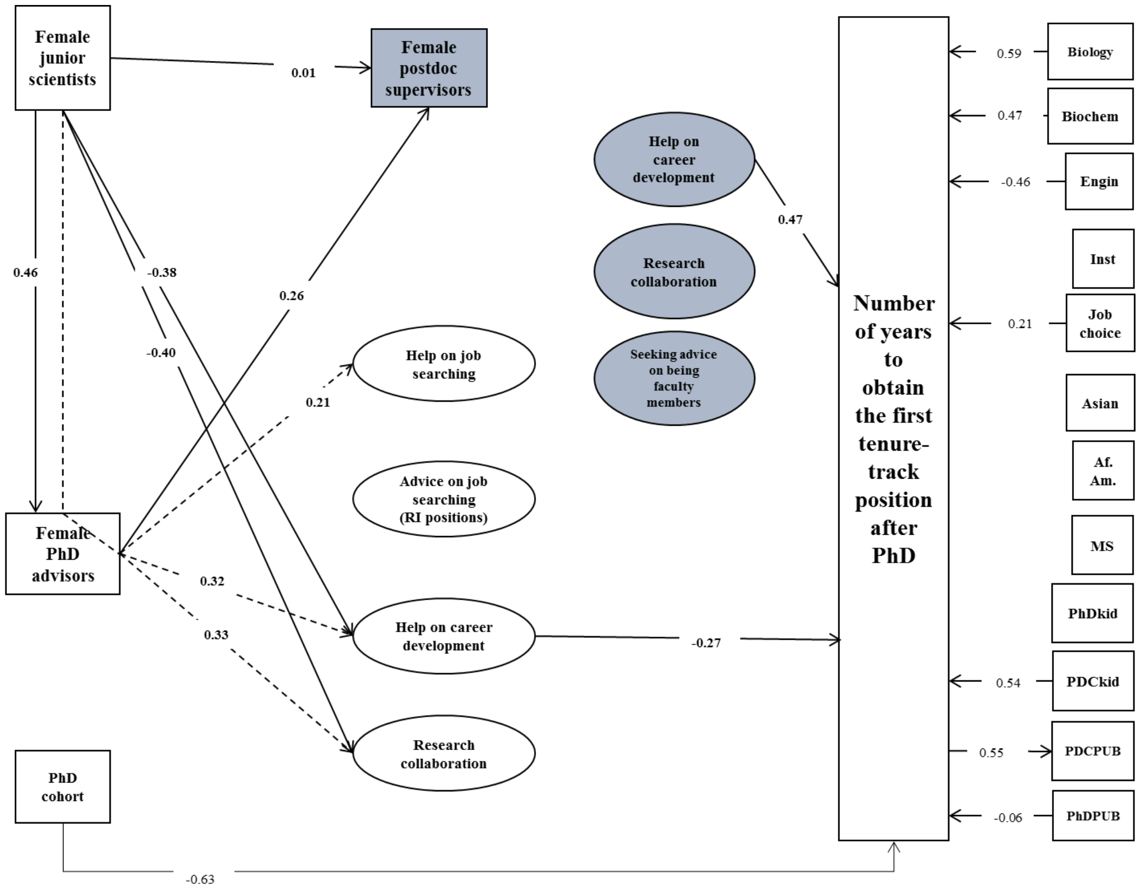

Figure 16. Visual Model of Significant Model Results Predicting STEM Faculty's Time to Obtain the First Tenure-track Position Among Those Who Are Currently at the Assistant Rank and Who Got a Tenure-track Job After Postdoctoral Training – Using Multiple Imputation Technique

Note 1: Dotted lines and arrows indicate indirect effects.

Note 2: **PhDPUB**: Total number of peer-reviewed journal articles published during and before PhD, **PDCPUB**: Total number of peer-reviewed journal articles published during postdoctoral period, **Biochem**: Biochemistry, **Engin**: Civil Engineering, **Inst**.: Current institution type, **PhDkid**: Having children during PhD, **PDCkid**: Having children during postdoctoral training, **MS**: Marital status, **Jobchoice**: Preferred career choice as finishing PhD

5.5.2.3. Additional findings in SEM model

In the postdoc group model that uses the sample of those who are currently at the assistant rank, SEM analyses find that several control variables have positive effects on STEM faculty early stage career development outcomes. Among the current assistant professors who completed postdoctoral training before getting the first tenure-track position, those who have greater numbers of peer-reviewed journal articles published during and before PhD (Non-imputed model: $\beta=-0.10$, $p<0.01$; imputed model: $\beta=-0.06$, $p<0.10$), who are in younger PhD cohorts (Non-imputed model: $\beta=-0.70$, $p<0.001$; imputed model: $\beta=-0.63$, $p<0.001$), and who are in STEM discipline of Civil Engineering (Non-imputed model: $\beta=-0.45$, $p<0.001$; imputed model: $\beta=-0.47$, $p<0.001$) reported shorter time to obtain the first tenure-track position.

Other control variables have negative effects on STEM faculty early stage career development outcomes, which referred to the longer time to obtain the tenure-track positions. STEM faculty members who had children during the postdoctoral period (Non-imputed model: $\beta=0.48$, $p<0.001$; imputed model: $\beta=0.54$, $p<0.001$), whose preferred career choice was tenure-track faculty position in a teaching-intensive environment, industry or government, or non-academic position (Non-imputed model: $\beta=0.24$, $p<0.001$; imputed model: $\beta=0.21$, $p<0.01$), and who are in STEM disciplines of Biology (Non-imputed model: $\beta=0.13$, $p<0.10$; imputed model: $\beta=0.59$, $p<0.05$) and Biochemistry (Non-imputed model: $\beta=0.13$, $p<0.10$; imputed model: $\beta=0.47$, $p<0.10$) reported longer to obtain the first tenure-track position.

5.5.2.4. SEM model evaluation: Goodness-of-fit

The chi-square test, the comparative fit index (CFI), and the root mean square error of approximation (RMSEA) results show that both non-imputed and imputed models fit the data well. For non-imputed model, Chi-square value is significant at a 0.001 threshold, CFI value is 0.926, and RMSEA value is 0.028. All three indicators show good fit. SEM analysis using imputed data has good fit as well. Chi-square value is significant at a 0.001 threshold, CFI value is 0.923, and RMSEA value is 0.032.

6. Conclusions

6.1. Overview

The purpose of this dissertation is to understand the effects of gender, mentoring resources, and gender homophily in mentoring dyads on STEM faculty early stage career advancement outcome. The core argument of this study is threefold. Gender differences in career development outcomes in academic STEM fields are due to gender bias. In particular, it takes longer for female STEM scientists to obtain a first tenure-track job because of the gender-biased job performance and commitment expectations. Second, this study argues that female scientists have disadvantages in receiving mentoring resources that are crucial for scholarly development and career progress. The last core argument is that the gender disparities in career advancement and receipt of mentoring resources can be alleviated through the same-gender mentoring dyads, because female mentees can receive more help and support from same-gender mentors.

To address and support the core arguments, this dissertation develops and tests an integrated theoretical framework incorporating Status Characteristics Theory, the concept of Mentoring and Social Capital Theory, and Ingroup Bias Theory. The integrated theoretical framework provides insights of combined effects of gender, mentoring, and gender homophily in mentoring dyads on junior scientists' career progress. For example, the integrated theoretical framework explains that female junior scientists receive less mentoring help and advice from their PhD advisors and postdoctoral supervisors, which in turn influences career advancement outcomes. The framework also accounts for the indirect effects of gender homophily in mentoring dyads on junior scientists' career advancement outcomes through the positive effects of gender homophily in the provision of mentoring help and advice. Using the integrated theoretical framework, hypotheses are developed to test direct and indirect influences on STEM scientists' early stage career advancement outcome.

Structural equation modeling (SEM) was used to test the hypotheses. A subset of academic STEM scientists who responded to the national online survey is used for the analysis. To test hypothesized relationships, two sets of empirical models were tested. One is the PhD only group that comprising survey respondents who obtained a tenure-track position without having postdoctoral training. The other is the postdoc group comprising those who completed postdoctoral training prior to obtaining a tenure-track position. The two empirical models are developed to reflect the different characteristics of the two groups in the analysis and to capture the influence of gender, mentoring resources, gender homophily, and STEM faculty early stage career advancement outcomes between two different groups. Two additional models are tested to enhance robustness of the SEM results as including mentoring resources variables indicating junior scientists' recent relationships with their PhD advisors and postdoctoral supervisors. Thus, in the additional models, the sub-sample comprised of respondents who are currently at the assistant ranks is used. Both PhD only group and postdoctoral group are analyzed for the assistant professor models as well.

Key findings indicate that, from both the PhD only group and the postdoc group using the full sample as well as the sub-sample of assistant professors, no direct gender effect on STEM faculty early stage career advancement outcomes when controlling for other variables including mentoring resources, gender homophily in mentoring dyads, research productivity, and domestic caregiving responsibilities. It may support recent study results concluding that there is no significant gender difference in career advancement outcomes. For example, Connolly, Lee, and Savoy (2015) found that there is no significant gender difference through the investigation of the extent to which gender affects being hired into a tenure-track position. Morrison, Rudd, and Nerad (2011) study demonstrates that no gender bias is detected in earlier stages of academic career advancement especially among the recent PhD cohorts those who earned their PhD in 1990s and 2000s. Moreover, Williams and Ceci's (2015) hiring experiments show a 2:1 hiring preference for female candidates compared to their male counterparts. In their experiment, they presented fictional faculty applications to current faculty. Fictional candidates had equivalently qualified and they only differed in gender.

Even though the finding of this dissertation indicates no gender difference in STEM faculty early stage career advancement outcome is aligned with the findings of recent studies present evidence, it may be too hasty to conclude that gender difference in faculty early stage career advancement outcome has disappeared. The above mentioned studies reveal limitations and face criticism. For example, Morrison et al.'s (2011) study result is not that it concludes that the gender bias in academic career advancement for junior scholars has disappeared. Instead, their study results show that the opportunity structure for female junior scholars' career development has been changed as the representation of female doctorates grows. Second, there may be a study design issue. In particular, Williams & Ceci's (2015) study faces criticism that their experiment fails to realistically simulate the actual faculty hiring process because the applicant reviewers knew that the candidates are hypothetical (Haynes & Sweedler, 2015). Third, such findings may be due to the complexity of faculty hiring process. Faculty hiring decision is influenced by multiple factors such as candidate's research productivity (Ceci et al., 2014), the prestige of the PhD origin (Zubieta, 2009), and strong letters of support (Williams & Ceci, 2015). For female candidates, family caregiving responsibility is discussed as additional critical determinant (Ceci & Williams, 2010; Gupta et al., 2005; Leahey, 2006; Misra et al., 2010).

Evidence of this study may not refute discussions of gender inequality in career advancement outcomes at early career stages due to the sample bias. The final samples used for the SEM in this study only include those who have already obtained tenure-track positions. In other words, the sample does not capture information of those who are currently in the job market while searching for a tenure-track job as holding a non-tenure-track positions or unemployed, or who already left the academy before getting a tenure-track job.

Other key findings (Hypotheses 3 through 5) obtained from the models using the full sample indicate direct and indirect gender effects on mentoring resources through the effect of gender homophily. SEM analyses from both PhD only group and postdoc group show that female junior scientists receive more mentoring resources when they have female PhD advisors although they receive the less mentoring resources from PhD advisors as compared to their male counterparts.

In the models using sub-sample of assistant professors, especially among those who did not completed the postdoctoral training before getting the tenure-track positions, SEM analyses yield interesting findings that mentoring resources do not have significant effects on STEM faculty's early stage career progress outcomes. As finding evidence from the data, it is concluded that some respondents in this group were competitive enough in the job market as candidates even without mentors' help and support because they were highly productive before receiving PhDs. The others might have not been in a great need of PhD advisor mentoring resources that are mostly oriented to help and support for applying to the research-intensive positions because their preferred career choices were non-research-intensive positions as they were finishing their PhDs.

The last but the most important finding that SEM analyses produce is the indirect gender effects on STEM faculty early stage career advancement outcome through the same-gender mentoring dyads and the mentoring resources provision in the same-gender mentoring dyads. For the PhD only group model using the full sample, female junior STEM scientists who have female PhD advisors conduct more research collaboration with their PhD advisors, both of which is associated with shorter time to obtain a tenure-track position. For the PhD only group model using the sub-sample of those who have assistant professorships, female junior STEM scientists who receive more help on their career development from female PhD advisors reported shorter time to obtain a tenure-track position.

The postdoc group model using the full sample provides results that female junior STEM scientists who have female PhD advisors receive help on researching the first tenure-track job as well as help on their research development from their PhD advisors, which are positively associated with female junior scientists' career advancement outcome. Also, for the postdoc group using the full sample, female junior STEM scientists who have female postdoctoral supervisors collaborate more with their supervisors, which is associated with shorter time to obtain the first tenure-track position. For the postdoc group model using the sub-sample of those who have assistant professorships, female assistant professors receiving more help from their female PhD advisors on their career development reported shorter time to obtain the first tenure-track position.

6.2. Theoretical implications

This dissertation offers theoretical contributions. The first theoretical contribution develops from the gender effects on receiving mentoring resources. More specifically, it offers the evidence supporting that female academic junior scientists have disadvantages in receiving mentoring resources from their PhD advisors and postdoctoral supervisors. To explain the integrated effects of gender and the mentoring on junior scientists' career progress, this dissertation used the Status Characteristics Theory (SCT), providing a foundation for understanding gender biased evaluations because of the gender stereotype, and the concept of mentoring. The incorporation of mentoring and SCT provide insights for understanding integrated effects of gender and mentoring on junior scientists' career progress. Further, it addresses the question of whether and to what extent female junior scientists' gender influences the extent of receiving mentoring help and advice, which in turn influences their career progress.

The next theoretical contribution is supporting the literature on the gender homophily mentoring dyads. Findings of the dissertation show the gender homophily effects in the creation of same-gender mentoring dyads as well as mentoring resource provision in the same-gender mentoring dyads. The findings confirm Ingroup Bias

Theory's (IBT) core arguments that individuals feel close to those who are similar to them (i.e., ingroup members), so they provide favorable evaluations and treatments towards ingroup members than outgroup members (Brewer, 1979, 1999, 2007; Hewstone et al., 2002). Findings of this dissertation add understandings of how the ingroup bias takes place where male-dominated culture is pervasive like the academic science. IBT argues that individuals are motivated to take actions to elevate the status of the ingroup if social comparisons result in negative group identity such as being discriminated and being regarded as the inferior group in the intergroup hierarchy (Tajfel & Turner, 1979; Cameron & Lalonde, 2001), which is to enhance self-esteem. Thus, female scientists tend to prefer other female scientists as they provide favored treatments and evaluations to improve group identities and elevate the overall status of female academic scientists in STEM fields.

The third and the last theoretical contribution of this dissertation is associated with the findings that female junior STEM scientists who have female PhD advisors receive mentoring resources from their PhD advisors and postdoctoral supervisors, which results in the positive impacts on their career advancement outcome. The findings support and emphasize that the same-gender mentoring dyad of Ph.D. advisors-students and postdoctoral supervisors-trainees is an essential career development tool for female scientists in the academic STEM. This dissertation's findings also discount the argument of previous studies inferring that female mentees who are in cross-gender mentoring dyads receive greater support (Sosik & Godshalk, 2005) and are more satisfied with their jobs (Ramaswami et al., 2010). Thus, findings from this study can provide insights for understanding mentoring dyads of PhD advisors-students and postdoctoral supervisors-trainees support and advice that are beneficial for junior scientists' career advancement.

6.3. Practical implications

This study has practical implications for universities that aim to promote a gender neutral career advancement by providing information that the same-gender mentoring dyads can improve female academic scientists' experiences in the workplace and enhance their career success. Findings from this study reveal that mentoring resources of collaborations between mentors and mentees as well as mentors' help on mentees' career development are the most critical to mentees' career advancement as compared to other mentoring resources. Through the findings, this study can provide information to academic institutions or any other type of organizations in the labor market that aim to nurture the effective mentoring systems and tools. Findings from this study are also meaningful for female faculty members. Citing Belkin (2003), Ceci et al. (2014) present a concept of 'opting out,' which describes that female academics tend to 'opt out' of their profession when their career competes with family responsibilities. Though the concept recognizes how career progression is hindered by the cultural and institutional pressures, it describes female faculty members as being helpless in the structure, failing to capture and acknowledge the ways women endeavor in their attempts toward career success. This study demonstrates that female scholars can make efforts through the creation of female-female mentoring dyad and try to receive more help and support from them to battle gender bias throughout the academic career paths and develop constructive ways of build up their career success.

6.4. Importance of this dissertation to science policy

This dissertation make contributions and broader impacts in public policy especially science policy. Educating and promoting female workforce in the profession is an important issue in the STEM field. Also, studies have highlighted that mentoring as well as the gender homophily in mentoring play important roles to reduce bias against female workers in the field and to enhance their job performance and job satisfaction, which leads to their career success in the field. The theoretical and empirical findings and contributions of this dissertation can provide information on the positive effects of gender homophily in the provision of the mentoring resources on female scientists' career advancement outcome to scholars, practitioners, and educators in STEM field. Consequently, this study can serve as an additional venue offering meaningful discussions for the female endeavor in the academic STEM.

6.5. Limitations

Although this dissertation offers theoretical and practical contributions, it is important to note that this study is not free from limitations. The first limitation of this study is related to the sampling bias. As briefly mentioned in the previous section, measures used in this study including domestic care responsibilities, research productivity, mentoring resources from PhD advisors and postdoctoral supervisors, or even time to obtain the first tenure-track position might be biased because the sample is limited to those who currently have faculty positions. In other words, the final sample used for this study does not capture individuals who are currently searching for a tenure-track job as holding non-tenure-track positions or who already left the fields before getting a tenure-track job. It means that academic scientists, especially female, with the highest amount of family responsibilities or work-family conflicts might not be included. This may be the reason that SEM models results of PhD only group and postdoc group do not support the direct gender effects on time to obtain the first tenure-track position among STEM faculty members.

Second, the research frame and model used in this study might generate different results if it is used in non-science fields. This research is based on the context of STEM fields in where female faculty members have long been underrepresented. The extent of the effects of gender and gender homophily on female faculty members' career advancement outcome might differ in academic fields where female faculty members are relatively well represented.

Third, this research may reveal limitations related to the data, especially because of omitted variables. There are multiple factors that give impacts on academic STEM faculty's career progress including faculty hiring and promotion. For example, faculty hiring decisions are influenced by job candidate's research productivity (Ceci et al., 2014), the prestige of the PhD origin (Zubieta, 2009), and strong letters of support (Williams & Ceci, 2015). Although there might be additional factors that determine STEM faculty's career progress in reality, limited variables are used to test relationships in this study. Omitted variables include organizational factors including the ranking of the institution where the respondents received their PhDs. Thus, the empirical model for this study might not fully capture all the complex causal factors that account for female academic scientists' time to obtain the first tenure-track.

6.6. Future research directions

Potential directions for future research include investigating the disparity in the labor markets. In the study limitation section, it is discussed that the research frame and model may generate different results if it is used in non-science fields. However, there are more opportunities than limitations as applying the research framework to account for any disparity or discrimination shaped by biases and stereotypes as well as the ways to alleviate negative impacts of the disparity or discrimination. In fact, the Status Characteristics Theory (SCT), the concept of mentoring, Social Capital Theory, and Ingroup Bias Theory do not limit their scopes to explain gender disparity but to explain disparities in the broader perspective about race/ethnicity, social status, disability, and sexual orientation.

Potential directions for future research include investigating the effects of mentoring in the broader perspective, for example, online mentoring. This study focuses on the one-on-one in-person mentoring relationships with PhD advisors and postdoctoral supervisors. As briefly discussed in the body of this study, however, mentors are not necessarily advisors or supervisors. Academic scientists may have ample mentoring relationships with other scholars outside of their departments, institutions, or even from other fields. Further, recent studies present that online mentoring can be an alternative approach provide mentoring resources for female scholars in academia. Many individual scholars actively utilize social media such as Facebook or Twitter to exchange research ideas, information about the conference, job opening, and grant opportunities. They can also share their personal experiences to manage department politics, collaborate with other scholars and organizations, interact with colleagues, student related issues, and work-family balance as faculty members, academic scholars, teachers, and laypeople. For example, recently, there have been coalitions and efforts organized online such as 'Women Also Know Stuff' or 'CareerWISE' that is a website designed to provide "instruction, practice, and vicarious role models, customized for women in STEM fields, in personal and interpersonal skills for overcoming discouragers, managing barriers, and expanding supports to fulfill personal and professional ambitions" (Dawson, Bernstein, & Bekki, 2015, p. 57). Thus, future research questions can start from how various forms of mentoring including the online mentoring support female scholars as well as mitigate gender biases in the academy.

References

Ensher, A.E., & Murphy, E.S. (1997). Effects of race, gender, perceived similarity, and contact on mentor relationships. *Journal of Vocational Behavior, 50*(3), 460-481.

Fagenson-Eland, E., Marks, M., & Amendola, K. (1997). Perceptions of mentoring relationships. *Journal of Vocational Behavior, 51*(1), 29-42.

Adamowicz, E. M. (2017). Why aren't women choosing STEM academic jobs? Observations from a small-group discussion at the 2016 American Society for Microbiology annual meeting. *FEMS Microbiology Letters, 364*(6), 1-4. doi:doi: 10.1093/femsle/fnx057

Ahern, K., & Manathunga, C. (2004). Clutch-starting stalled research students. *Innovative Higher Education, 28*(4), 237-254.

Allen, T. D., Day, R., & Lentz, E. (2005). The role of interpersonal comfort in mentoring relationships. *Journal of Career Development, 31*(3), 155-169.

Allen, T. D., & Eby, L. T. (2004). Factors related to mentor reports of mentoring functions provided: Gender and relational characteristics. *Sex Roles, 50*(1), 129-139.

Allen, T. D., Eby, L. T., Poteet, M. L., Lentz, E., & Lima, L. (2004). Career benefits associated with mentoring for protégés: A meta-analysis. *Journal of Applied Psychology, 89*(1), 127-136.

Allison, P. D. (2000). Multiple imputation for missing data: A cautionary tale. *Sociological Methods & Research, 28*(3), 301-309.

Allison, P. D. (2003). Missing Data Techniques for Structural Equation Modeling. *Journal of Abnormal Psychology, 112*(4), 545-557.

Allison, P. D. (2012). Why you probably need more imputations than you think. Retrieved from https://statisticalhorizons.com/more-imputations

Austin, A. E., & McDaniel, M. (2006). Preparing the professoriate of the future: Graduate student socialization for faculty roles. *Higher Education: Handbook of Theory and Research, 21,* 397-456.

Barnes, B. J. (2010). The nature of exemplary advisor's expectations and the ways they may influence doctoral persistence. *Journal of College Student Retention: Research, Theory & Practice, 11*(3), 323-343.

Barnes, B. J., & Austin, A. E. (2009). The role of doctoral advisors: A look at advising from the advisor's perspective. *Innovative Higher Education, 33*(5), 297-315.

Belkin, L. (2003). The opt-out revolution. *New York Times Magazine*. Retrieved from http://www.nytimes.com/2003/10/26/magazine/the-opt-out-revolution.html?rref=collection%2Fbyline%2Flisa-belkin&action=click&contentCollection=undefined&region=stream&module=stream_unit&version=search&contentPlacement=1&pgtype=collection

Berger, J., Cohen, B., & Morris Zelditch, J. (2015). Status characteristics and expectation states.

Bettencourt, A., & Bartholow, B. D. (1998). The importance of status legitimacy for intergroup attitudes among numerical minorities. *Journal of social issues, 54*, 758-775.

Bickel, J. (2014). How men can excel as mentors of women. *Academic Medicine, 98*(8), 1100-1102.

Bilimoria, D., Joy, S., & Liang, X. (2008). Breaking barriers and creating inclusiveness: lessons of organizational transformation to advance women faculty in academic science and engineering. *Human resource management*, *47*(3), 423-444.

M. Blair-Loy, L. E. Rogers, D. Glaser, Y. L. A. Wong, D. Abraham, & P. C. Cosman. (2017). Gender in engineering departments: Are there gender differences in interruptions of academic job talks? Social Sciences, 6(29), 1-19.

Blake-Beard, S., Bayne, M. L., Crosby, F. J., & Muller, C. B. (2011). Matching by Race and Gender in Mentoring Relationships: Keeping our Eyes on the Prize. *Journal of social issues*, *67*(3), 622-643.

Bodenhausen, G. V., Macrae, C. N., & Garst, J. (1998). Stereotypes in thought and deed: Social-cognitive origins of intergroup discrimination. In C. Sedikides, J. Schopler, & C. A. Insko (Eds.), *Intergroup cognition and intergroup behavior* (pp. 311-335). Mahwah, NJ: Lawrence Erlbaum Associates.

Bourdieu, P. (1985). The forms of capital. In J. G. Richardson (Ed.), *Handbook of Theory and Research for the Sociology of Education* (pp. 241-258). New York, NY: Greenwood.

Bozeman, B., & Feeney, M. K. (2007). Toward a useful theory of mentoring a conceptual analysis and critique. *Administration & Society, 39*(6), 719-739.

Brainard, S. G., & Ailes-Sengers, L. (1994). Mentoring female engineering students: A model program at the University of Washington. *Journal of Women and Minorities in Science and Engineering, 1*(2), 123-135. doi:10.1615/JWomenMinorScienEng.v1.i2.30

Brainard, S. G., & Carlin, L. (1998). A Six-Year longitudinal study of undergraduate women in engineering and science. *Journal of Engineering Education, 87*(4), 369-375.

Brass, D. J., & Krackhardt, D. (1999). The social capital of twenty-first century leaders. , 179-194. In J. G. Hunt & R. L. Phillips (Eds.), *Out-of-the-box leadership: transforming the twenty-first-century army and other top-performing organizations* (pp. 179-194). Bradford, United Kingdom: Emerald Group Publishing Limited.

Brewer, M. B. (1979). In-group bias in the minimal intergroup situation: a cognitive-motivational analysis. *Psychological Bulletin, 86*(2), 307-324.

Brewer, M. B. (1999). The psychology of prejudice: Ingroup love and outgroup hate? *Journal of social issues, 55*(3), 429-444.

Brewer, M. B. (2007). The social psychology of intergroup relations: social categorization, ingroup bias, and outgroup prejudice. In A. W. Kruglanski & E. T. Higgins (Eds.), *Social psychology: handbook of basic principles* (2nd ed., pp. 695-715). **New York, NY**: Guilford Publications.

Brown, J. R., & Finkelstein, A. (2009). The private market for long-term care insurance in the United States: a review of the evidence. *The Journal of Risk and Insurance, 76*(1).

Burke, R., McKeen, C., & McKenna, C. (1990). Sex differences and cross-sex effects on mentoring: Some preliminary data. *Psychological Reports, 67*(3), 1011-1023.

Burt, R. S. (2000). The network structure of social capital. *Research in organizational behavior, 22*, 345-423.

Byrne, B. M. (2012). *Structural equation modeling with Mplus: Basic concepts, applications, and programming*. New York, NY: Routledge.

Cameron, J. E., & Lalonde, R. N. (2001). Social identification and gender-related ideology in women and men. *British Journal of Social Psychology, **40***(1), 59-77.

Cameron, S. W., & Blackburn, R. T. (1981). Sponsorship and academic career success. *The Journal of Higher Education, 52*(4), 369-377.

Campbell, K. E., Marsden, P. V., & Hurlber, J. S. (1986). Social resources and socioeconomic status. *Social Networks, 8*, 97-117.

Carter, S. L., Rourke, S. B., Murji, S., Shore, D., & Rourke, B. P. (2003). Cognitive complaints, depression, medical symptoms, and their association with neuropsychological functioning in HIV infection: A structural equation model analysis. *Neuropsychology, 17*(3), 410-419.

Castilla, E. J. (2008). Gender, race, and meritocracy in organizational careers. *American journal of sociology, 113*(66), 1479-1526.

Castilla, E. J., & Bernard, S. (2010). The paradox of meritocracy in organizations. *Administrative Science Quarterly, 55*(4), 543-576.

Ceci, S. J., Ginther, D. K., Kahn, S., & Williams, W. M. (2014). Women in academic science: a changing landscapt. *Psycholofical Science in the Public Interest, 15*(3), 75-141. doi:10.1177/1529100614541236

Ceci, S. J., & Williams, W. M. (2010). Understanding current causes of women's underrepresentation in science. *Proceedings of the National Academy of Sciences, 108*(8), 3157-3162.

Ceci, S. J., & Williams, W. M. (2015). Women have substantial advantage in STEM faculty hiring, except when competing against more-accomplished men. *Frontiers in psychology, 6*(1-10).

Chesler, N. C., Single, P. B., & Mik, B. (2003). On belay: Peer-mentoring and adventure education for women faculty in engineering. *Journal of Engineering Education, 92*(3), 257-262.

Clark, R. A., Harden, S. L., & Johnson, W. B. (2000). Mentor relationships in clinical psychology doctoral training: Results of a national survey. *Teaching of psychology, 27*(4), 262-268.

Clewell, B. C., & Campbell, P. B. (2002). Taking stock: Where we've been, where we are, where we're going. *Journal of Women and Minorities in Science and Engineering, 8*, 255-284.

Cole, J. R., & Zuckerman, H. (1984). The productivity puzzle. In *Advances in Motivation and Achievement*. Greenwich, CT: JAI Press.

Coleman, J. S. (1988). Social capital in the creation of human capital. *American journal of sociology, 94*, S95-S120.

Coleman, J. S. (1990). *Foundations of social capital theory*. Cambridge, Mass: Belknap.

Connolly, M. R., Lee, Y.-G., & Savoy, J. N. (2015). *Faculty hiring and tenure by sex and race: new evidence from a national survey*. Paper presented at the Annual Meeting of the American Education Research Association, Chicago, IL.

Correll, S., Benard, S., & Paik, I. (2007). Getting a job: Is there a motherhood penalty? . *The American Journal of Sociology, 112*(5), 1297-1338.

Correll, S., & Bernard, S. (2006). Biased estimators? Comparing status and statistical theories of gender discrimination. *Social Psychology of the Workplace, 23*, 89-116.

Correll, S., & Ridgeway, C. (2003). Expectation states theory. In J. Delmater (Ed.), *Handbook of social psychology* (pp. 29-51). New York, NY: Kluwer Academic Press.

Creighton, L., Creighton, T., & Parks, D. (2010). Mentoring to degree completion: Expanding the horizons of doctoral protégés. . *Mentoring & Tutoring: Partnership in Learning, 18*(1), 39-52.

Crookston, B. (1972). A developmental view of academic advising as teaching. *Journal of College Student Personnel, 13*, 12-17.

Cullen, D. L., & Luna, G. (1993). Women mentoring in academe: Addressing the gender gap in higher education. *Gender and Education, 5*(2), 125-137.

Curtis, J. W. (2011). *Persistent inequity: Gender and academic employment*. Paper presented at the American Association of University Professors, Washington, DC. https://www.aaup.org/NR/rdonlyres/08E023AB-E6D8-4DBD-99A0-24E5EB73A760/0/persistent_inequity.pdf

Dawson, A. E., Bernstein, B. L., & Bekki, J. M. (2015). Providing the psychosocial benefits of mentoring to women in STEM: CareerWISE as an online solution. *New Directions for Higher Education, **171***, 53-62.

Dietz, J. S., & Bozeman, B. (2005). Academic careers, patents, and productivity: industry experience as scientific and technical human capital. *Research policy, 34*(3), 349-367.

Drago, R., Colbeck, C., Stauffer, K. D., Pirretti, A., Burkum, K., Fazioli, J., . . . Habasevich, T. (2006). The avoidance of bias against caregiving. *American Behavioral Scientist*, *49*(9), 1222-1247.

Durley, J. R. (2006). *Female Mentors' Mentoring Experiences: The Role of Protégé Gender in Determining Processes and Outcomes.* (Doctor of Philosophy), University of Georgia, Athens, Georgia.

Dutt, K., Pfaff, D. L., Bernstein, A. F., Dillard, J. S., & Clock, C. J. (2016). Gender differences in recommendation letters for postdoctoral fellowships in geoscience. *Nature Geoscience*, *9*, 805-809. doi:10.1038/NGEO2819

Eagly, A. H., & Karau, S. J. (2002). Role congruity theory of prejudice toward female leaders. *Psychological Review, 109*(3), 573-598.

Eby, L. T. (1997). Alternative forms of mentoring in changing organizational environments: A conceptual extension of the mentoring literature. *Journal of Vocational Behavior, 51*, 125-144.

Emmerik, I. H. v. (2006). Gender differences in the creation of different types of social capital: A multilevel study. *Social Networks, 28*, 24-37.

Etzkowitz, H., Kemelgor, C., & Uzzi, B. (2000). *Athena unbound: the advancement of women in science and technology* (Vol. New York, NY): Cambridge University Press.

Faghihi, F. Y. (1998). *A study of factors related to dissertation progress among doctoral candidates: Focus on student research self-efficacy as a result of their research training and experiences.* University of Memphis, Memphis, TN.

Feeney, M., & Welch, E. (working paper). Analyzing common narratives: an empirical investigation of women in academic science.

Feeney, M. K. (2006). Mentoring women in the public sector: Expectations and realities. *International Journal of Learning and Change*, *1*(4), 381-406.

Forrett, M. L., & Dougherty, T. W. (2004). Networking behaviors and career outcomes: differences for men and women? *Journal of Organizational Behavior, 25*(3), 419-437.

Fox, M. F., Fonseca, C., & Bao, J. (2011). Work and family conflict in academic science: patterns and predictors among women and men in research university. *Social Studies of Science*, *41*(5), 715-735. doi:10.1177/0306312711417730

Fox-Wasylyshyn, S. M., & El-Masri, M. M. (2005). Handling missing data in self-report measures. *Research in nursing & health, 28*(6), 488-495.

Gardner, S. K., & Blackstone, A. (2013). Putting in your time: Faculty Experiences in the Process of Promotion to Professor. *Innovative Higher Education*, *38*(5), 411-425. doi:10.1007/s10755-012-9252-x

Gelso, C. J. (1993). On the making of a scientist-practioner: A theory of research training in professional psychology. *Professional Psychology: Research and Practice, 24*(4), 468-476.

Ghoshal, J. N. S. (1998). Social capital, intellectual capital, and the organizational advantage. *The Academy of Management Review, 23*(2), 242-266.

Gilbert, L. A. (1985). Dimensions of same-gender student-faculty role-model relationships. *Sex Roles, 12*(1), 111-123.

Ginther, D., & Kahn, S. (2006). Does science promote women? Evidence from academia 1973-2001. Retrieved from

Girves, J. E., & Wemmerus, V. (1988). Developing models of graduate student degree progress. *Journal of Higher Education, 59*(2), 163-189.

Goldberg, E. R. (2005). *The contribution of advisor behaviours to measures of graduate student success and satisfaction.*, The University of Western Ontario, Ontario, Canada.

Goldstein, E. (1979). Effect of same-sex and cross-sex role models on the subsequent academic productivity of scholars. *American Psychologist, 34*(5).

Gottschall, S. (2014). *The influences of sex, gender identity, and power on faculty-graduate student relational mentoring and its association with student psychological health.* (Doctor of Philosophy), Carleton University, Ottawa, Canada.

Graham, J. W., Olchowski, A. E., & Gilreath, T. D. (2007). How many imputations are really needed? Some practical clarifications of multiple imputation theory. *Prevention Science, 8*(3), 206-213.

Gupta, N., Kemelgor, C., Fuchs, S., & Etzkowitz, H. (2005). Triple burden on women in science: a cross-cultural analysis. *Current Science, 89*(8), 1382-1386.

Hawley, P. (1993). *Being bright is not enough: The unwritten rules of doctoral studies*. Springfield, IL: Charles C. Thomas.

Haynes, C., & Sweedler, J. (2015). Are we there yet? Biases in hiring women faculty candidates. *American Chemical Society*, 6989.

Heilman, M. (2012). Gender stereotypes and workplace bias. *Research in organizational behavior, 32*(113-135).

Heilman, M. (2015). Gender Stereotypes: Impediments to Women's Career Progress. In I. M. Welpe, P. Brosi, L. Ritzenhöfer, & T. Schwarzmüller (Eds.), *Auswahl von Männern und Frauen als Führungskräfte: Perspektiven aus Wirtschaft, Wissenschaft, Medien und Politik* (pp. 73-84). Wiesbaden: Springer Fachmedien Wiesbaden.

Heilman, M., & Hayes, M. (2005). No credit where credit is due: attributional rationalization of women's success in male-female teams. *Journal of Applied Psychology, 90*(5), 905-916.

Heinrich, K. T. (1995). Doctoral advisement relationships between women: On friendship and betrayal. *The Journal of Higher Education, 66*(4), 447-469.

Hewstone, M., Rubin, M., & Willis, H. (2002). Intergroup bias. *Annual Review of Psychology, 53*(1), 575-604.

Hezlett, S. (2005). How Do Formal Mentors Assist Their Proteges? A Study of Mentors Assigned to Cooperative Education Students and Interns, 450-457. Retrieved from http://files.eric.ed.gov/fulltext/ED492458.pdf

Hezlett, S. A., & Gibson, S. K. (2007). Linking mentoring and social capital: Implications for career and organization development. *Advances in Developing Human Resources, 9*(3), 384-411.

Hollingsworth, M. A., & Fassinger, R. E. (2002). The role of faculty mentors in the research training of counseling psychology doctoral students. *Journal of Counseling Psychology, 49*(3), 324-330.

Hoyle, R. H. (2011). *Structural equation modeling for social and personality psychology*. Thousand Oaks, CA: Sage Publications.

Hoyle, R. H. (2012). Model specification in structural equation modeling. In R. H. Hoyle (Ed.), *Handbook of structural equation modeling* (pp. 126-144). New York, NY: The Guilford Press.

Ibarra, H. (1992). Homophily and differential returns: sex differences in network structure and access in an advertising firm. *Administrative Science Quarterly, 37*, 422-447.

Inesi, M. E., & Cable, D. N. (2015). When accomplishments come back to haunt you: The negative effect of competence signals on women's performance evaluations. *Personnel Psychology*, *68*(3), 615-657.

Ingram, S., Bruning, S., & Mikawoz, I. (2009). Career and mentoring satisfaction among Canadian engineers: Are there differences based on gender and company-specific undergraduate work experience? . *Journal of Engineering Education, 98*(2), 131-144.

Jahanshahi, K., Jin, Y., & Williams, I. (2015). Direct and indirect influences on employed adults’ travel in the UK: New insights from the National Travel Survey data 2002–2010. *Transportation Research Part A: Policy and Practice, 80*, 288-306.

Johnson, B. W. (2007). Transformational supervision: When supervisors mentor. *Professional Psychology: Research and Practice, 38*(3), 259-267.

Johnson, W. B. (2014). Mentoring in psychology education and training: A mentoring relationship continuum model. In W. B. Johnson & N. J. Kaslow (Eds.), *The Oxford handbook of education and training in professional psychology* (pp. 272-290). New York, NY: Oxford University Press.

Kirchmeyer, C. (2005). The effects of mentoring on academic careers over time: Testing performance and political perspectives. *Human Relations, 58*(5), 637-660.

Kram, K. (1983). Phases of the mentor relationship. *Academy of Management Journal, 26*(4), 608-625.

Kram, K. E. (1985). *Mentoring at work: Developmental relationships in organizational life*. Lanham, Maryland: University Press of America.

Kram, K. E. (1988). *Mentoring at work: developmental relationships in organizational life*. Lanham, Maryland: University Press of America.

Krefting, L. A. (2003). Intertwined discourses of merit and gender: Evidence from academic employment in the USA. *Gender, Work & Organization, 10*(2), 260-278. doi:10.1111/1468-0432.t01-1-00014

Lawrence, J. H., Celis, S., & Ott, M. (2014). Is the tenure process fair? what cafulty think. *The Journal of Higher Education, 85*(2), 155-192.

Leahey, E. (2006). Gender differences in productivity: research specialization as missing link. *Gender & Society, 20*(6), 754-780. doi:10.1177/0891243206293030

Lin, N. (1999). Social networks and status attainment. *Annual Review of Sociology, 25*, 467-487.

Lin, N. (2001). *Social capital: a theory of social structure and action*. New York, NY: Cambridge University Press.

Long, J. S. (1978). Productivity and Academic Position in the Scientific Career. *American Sociological Review, 43*, 880-908.

Long, J. S., Allison, P. D., & McGinnis, R. (1993). Rank advancement in academic careers: sex differences and the effects of productivity. *American Sociological Review, 58*, 703-722.

Long, J. S., & Fox, M. F. (1995). Scienfitic careers: universalism and particularism. *Annual Review of Sociology, 21*(45-71).

Lovitts, B. E. (2001). *Leaving the ivory tower: The causes and consequences of departure from doctoral study*. New York, NY: Rowman & Littlefield.

Lundblad, V. J. (2017). Lundblad v. Salk Institute for Biological Studies. 37-2017-00025248-CU-OE-CTL. Retrieved from http://www.sciencemag.org/sites/default/files/Salk.lawsuit.Vicki_.Lundblad.pdf

Lundquist, J., & Misra, J. (2015). The Clogged Pipeline. *Inside Higher Ed*.

Lutter, M., & Schröder, M. (2014). *Who becomes a tenured professor, and why? Panel data evidence from German sociology, 1980-2013*. MPIfG Discussion Paper, No. 14/19.

Lyons, W., Scroggins, D., & Rule, P. B. (1990). The mentor in graduate education. *Studies in Higher Education, 15*(3), 277-285.

MacDonald, C., & Williams-Jones, B. (2009). Supervisor–student relations: Examining the spectrum of conflicts of interest in bioscience laboratories. *Accountability in research, 16*(2), 106-126.

Main, J. B. (2011). *Doctoral Student-Faculty Advisor Relationships: The Impact Of Gender Matching On Student Educational And Employment Outcomes.* Cornell University, Ithaca, NY.

Massachusetts Institute of Technology. (1999). *A Study on the Status of Women Faculty in Science at MIT: How a Committee on Women Faculty came to be established by the Dean of the School of Science, what the Committee and the Dean learned and accomplished, and recommendations for the future*. Retrieved from http://web.mit.edu/fnl/women/women.pdf

Misra, J., Lundquist, J., Holmes, E., & Agiomavritis, S. (2010). Associate professors and gendered barriers to advancement. Retrieved from http://people.umass.edu/misra/Joya_Misra/work-life_files/Associate%20Professors%20and%20Gendered%20Barriers%20to%20Advancement%20Full%20Report.pdf

Monsour, M., & Corman, S. (1991). Social and task functions of the dissertation partner: One way of avoiding terminal ABD status. *Communication Education, 49*, 180-186.

Morgan, S. L., Gelbgiser, D., & Weeden, K. A. (2013). Feeding the pipeline: Gender, occupational plans, and college major selection. *Social Science Research, 42*(4), 989-1005. doi:https://doi.org/10.1016/j.ssresearch.2013.03.008

Morrison, E., Rudd, E., & Nerad, M. (2011). Onto, up, off the academic faculty ladder: The gendered effects of family on career transitions for a cohort of social science PhDs. *The Review of Higher Education, 34*(4), 525-553.

Moss-Racusin, C. A., Dovidio, J. F., Brescoll, V. L., Graham, M. J., & Handelsman, J. (2012). Science faculty's subtle gender biases favor male students. *Proceedings of the National Academy of Sciences, 109*(41), 16474-16479.

Mullen, E. J. (1994). Framing the mentoring relationship as an information exchange. *Human Resource Management Review, 4*(3), 257-281.

Muschallik, J., & Pull, K. (2016). Mentoring in higher education: does it enhance mentees' research productivity? *Education Economics, 24*(2), 210-223.

Mussweiler, T., & Ockenfels, A. (2013). Similarity increases altruistic punishment in humans. *Proceedings of the National Academy of Sciences, 110*(48), 19318-19323.

National Research Council. (2010). Gender differences at critical transitions in the careers of science, engineering, and mathematics faculty. In *Gender differences at* *critical transitions in the careers of science, engineering, and mathematics faculty* (pp. 116-152). Washington, DC: The National Academies Press.

National Science Board. (2012). *Science & Engineering Indicators 2012*. Retrieved from Arlington, VA:

National Science Board. (2016). *Science & Engineering Indicators 2016*. Retrieved from Arlington, VA:

National Science Foundation. (2009). *Characteristics of Doctoral Scientists and Engineers in the United States: 2006*. Retrieved from Arlington, VA: https://wayback.archive-it.org/5902/20160210152400/http://www.nsf.gov/statistics/nsf09317/

Nerad, M., & Cerny, J. (1999). Postdoctoral patterns, career advancement, and problems. *Science, 285*(5433), 1533-1535.

Nettles, M. T., & Millett, C. M. (2006). *Three magic letters: Getting to Ph.D.* Baltimore, MD: The Johns Hopkins University Press.

Newman, M. A. (1994). Gender and Lowi's thesis: implication for career advancement. *Public Administration Review, 54*(3), 277-284.

Newton, S. H. (2013). *Gender differences in STEM academic career paths.* (Doctor of Philosophy), Georgia Institute of Technology, Atlanta, GA.

Noe, R. A., Greenberger, D. B., & Wang, S. (2002). Mentoring: What we know and where we might go. In Research in personnel and human resources management (pp. 129-173). Emerald Group Publishing Limited. In *Research in Personnel and Human Resources Management (Research in Personnel and Human Resources Management, Volume 21)* (pp. 129-173): Emerald Group Publishing Limited.

Nolan, S. A., Buckner, J. P., Marzabadi, C. H., & Kuck, V. J. (2008). Training and mentoring of chemists: A study of gender disparity. *Sex Roles, 58*(3-4), 235-250.

O'Leary, V. E., & Wallston, B. S. (1982). Women, Gender, and Social Psychology *Review of Personality and Social Psychology, 2*, 9-43.

Over, R., Over, J., Meuwissen, I., & Lancaster, S. (1990). Publication by men and women with same-sex and cross-sex PhD supervision. *Higher Education, 20*(4), 381-391.

Paglis, L. L., Green, S. G., & Bauer, T. N. (2006). Does adviser mentoring add value? A longitudinal study of mentoring and doctoral student outcomes. *Research in Higher Education, 47*(4), 451-476.

Peng, C.-Y. J., Harwell, M., Liou, S.-M., & Ehman, L. H. (2006). *Advances in missing data methods and implications for educational research*. Charlotte, NC: Information Age Publishing.

Perna, L. W. (2001). Sex and race differences in faculty tenure and promotion. *Research in Higher Education, 42*(5), 541-567.

Phinney, J. S., Campos, C. M. T., Kallemeyn, D. M. P., & Kim, C. (2011). Processes and outcomes of a mentoring program for Latino college freshmen. *Journal of social issues, 67*(3), 599-621.

Platow, M. J. (2012). PhD experience and subsequent outcomes: a look at self-perceptions of acquired graduate attributes and supervisor support. *Studies in Higher Education and Ageing, 37*(1), 103-118.

Ragins, B. R. (1999). Gender and mentoring relationships: A review and research agenda for the next decade. In G. N. Powell (Ed.), *Handbook of gender and work* (pp. 347-370). Thousand Oaks, CA: Sage Publications.

Ragins, B. R., Cotton, J. L., & Miller, J. S. (2000). Marginal mentoring: The effects of type of mentor, quality of relationship, and program design on work and career attitudes. *Academy of Management Journal, 43*(6), 1177-1194.

Raymond, M. R., & Roberts, D. M. (1987). A comparison of methods for treating incomplete data in selection research. *Educational and Psychological Measurement, 47*(1), 13-26.

Reskin, B. F. (2000a). The proximate causes of employment discrimination. *Contemporary Sociology, 29*(2), 319-328.

Reskin, B. F. (2000b). Getting it right: Sex and race inequality in work organizations. *Annual Review of Sociology, 26*(1), 707-709.

Richey, C. A., Gambrill, E. D., & Blythe, B. J. (1988). Mentor relationships among women in academe. *Affilia, 3*(1), 34-47.

Ridgeway, C. (2011). *Framed by gender: How gender inequality persists in the modern world*. New York, NY: Oxford University Press.

Ridgeway, C., & Correll, S. (2004). Unpacking the gender system: A theoretical perspective on gender beliefs and social relations. *Gender & Society, 18*(4), 510-531.

Ridgeway, C., & Smith-Lovin, L. (1999). The gender system and interaction. *Annual Review of Sociology, 25*(1), 191-216.

Rosser, S. V., & Taylor, M. Z. (2009). Why are we still worried about women in science. *Academe, 95*(3), 7-10.

Rossiter, M. W. (1993). The Matthew Matilda effect in science. *Social Studies of Science, 23*(2), 325-341.

Roth, P. L. (1994). Missing data: A conceptual review for applied psychologists. *Personnel Psychology, 47*(3), 537-560.

Sanders, J. M., & Wong, H. Y. (1985). Graduate training and initial job placement. *Sociological inquiry, 55*(2), 154-169.

Schafer, J. L. (1999). Multiple imputation: a primer. *Statistical Methods in Medical Research, 8*, 3-15.

Schlomer, G. L., Bauman, S., & Card, N. A. (2010). Best practices for missing data management in counseling psychology. *Journal of Counseling Psychology, 57*(1), 1-10.

Schlosser, L. Z., & Foley, P. F. (2008). Ethical issues in multicultural student-faculty mentoring relationships in higher education. *Mentoring and Tutoring: Partnership in Learning, 16*, 63-75.

Schlosser, L. Z., & Kahn, J. H. (2007). Dyadic perspectives on advisor-advisee relationships in counseling psychology doctoral programs. *Journal of Counseling Psychology, 54*(2), 211-217.

Schlosser, L. Z., Knox, S., Moskovitz, A. R., & Hill, C. E. (2003). qualitative study of the graduate advising relationship: The advisee perspective. *Journal of Counseling Psychology, 50*, 178-188.

Schlosser, L. Z., Lyons, H. Z., Talleyrand, R. M., Kim, B. S. K., & Johnson, W. B. (2011). Advisor-advisee relationships in graduate training programs. *Journal of Career Development, 38*(1), 3-18.

Schroeder, D. S., & Mynatt, C. R. (1999). Graduate students' relationships with their male and female major professors. *Sex Roles, 40*(5), 393-420.

Schumacker, R. E., & Lomax, R. G. (2004). *A beginner's guide to structural equation modeling* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Assoicates.

Shakeshaft, C. (1987). *Women in educational administration*. Newbury Park, CA: Sage Publications.

Sheltzer, J. M., & Smith, J. C. (2014). Elite male faculty in the life sciences employ fewer women. *Proceedings of the National Academy of Sciences, 111*(28), 10107-10112.

Sinclair, M. (2004). *The pedagogy of'good'PhD supervision: A national cross-disciplinary investigation of PhD supervision*. Canberra, Austraila: Department of Education, Science and Training.

Smeby, J.-C. (2000). Same-gender relationships in graduate supervision. *Higher Education, 40*(1), 53-67.

Smith-Doerr, L. (2006). Stuck in the middle: Doctoral education ranking and career outcomes for life scientists. *Bulletin of Science, Technology & Society, 26*(3), 243-255.

Sosik, J. J., & Godshalk, V. M. (2000). The role of gender in mentoring: Implications for diversified and homogenous mentoring relationships. *Journal of Vocational Behavior, 57*(1), 102-122.

Sosik, J. J., & Godshalk, V. M. (2005). Examining gender similarity and mentor's supervisory status in mentoring relationships. *Mentoring & Tutoring: Partnership in Learning, 13*(1), 39-52.

Sprengers, M., Tazelaar, F., & Flap, H. D. (1988). Social resources, situational constraints, and re-employment. *Netherlands Journal of Sociology, 24*(2), 98-116.

Stroude, A., Bellier-Teichmann, T., Cantero, O., Dasoki, N., Kaeser, L., Ronca, M., & Morin, D. (2015). Mentoring for women starting a PhD: A "free zone" into academic identity. *International Journal of Mentoring and Coaching in Education, 4*(1), 37-52.

Su, X. (2013). The impacts of postdoctoral training on scientists' academic employment. *The Journal of Higher Education*, *84*(2), 239-265.

Tepper, B. J. (1995). Upward maintenance tactics in supervisory mentoring and nonmentoring relationships. *Academy of Management Journal*, *38*(4), 1191-1205.

Thurgood, L., Golladay, M. J., & Hill, S. T. (2006). *US Doctorates in the 20th Century*. Retrieved from Arlington, VA:

Toren, N. (1993). The temporal dimension of gender inequality in academia. *Higher Education, 25*, 439-455.

Toutkoushian, R. K., & Bellas, M. L. (1999). Faculty time allocations and research productivity: gender, race and family effects *Review of Higher Education, 22*(4), 367-390.

Turban, D. B., Dougherty, T. W., & Lee, F. K. (2002). Gender, race, and perceived similarity effects in developmental relationships: The moderating role of relationship duration. *Journal of Vocational Behavior, 61*(2), 240-262.

Turco, C. J. (2010). Cultural foundations of tokenism: Evidence from the leveraged buyout industry. *American Sociological Review, 75*(6), 894-913.

Turk-Bicakci, L., Berger, A., & Haxton, C. (2014). The nonacademic careers of STEM PhD holders *Broadening Participation in STEM Graduate Education*. Retrieved from https://pdfs.semanticscholar.org/0641/9dca81bb507871f8be00ccfdcdeab51c54c5.pdf

Wadman, M. (2017a). Salk Institute under fire for 'smear' on women suing it for discrimination. *Science*.

Wadman, M. (2017b). Two female scientists sue Salk Institute, alleging discrimination at 'old boys club'. *Science*.

Wagner, D. G., & Berger, J. (1993). Status Characteristics Theory: The Growth of a Program. In J. Berger & M. Z. Jr. (Eds.), *Theoretical Research Programs: Studies in the Growth of Theory*. Stanford, CA: Stanford University Press.

Waldeck, J. H., Orrego, V. O., Plax, T. G., & Kearney, P. (1997). Graduate student/faculty mentoring relationships: Who gets mentored, how it happens, and to what end. *Communication Quarterly*, *45*(3), 93-109.

Wanberg, C. R., Welsh, E. T., & Hezlett, S. A. (2003). Mentoring research: A review and dynamic process model. In J. J. Martocchio & G. R. Ferris (Eds.), *Research in personnel and human resources management* (Vol. 22, pp. 39-124). Oxford, UK: Elsevier Science.

Wang, J., & Wang, X. (2012). *Structural Equation Modeling: Applications Using Mplus*. West Sussex, UK: John Wiley & Sons.

Ward, K., & Wolf-Wendel, L. (2004). How safe is it to make time for family? *Academe, 90*(6), 28-31.

Wei, T. E., Levin, V., & Sabik, L. M. (2012). A referral is worth a thousand ads: Job search methods and scientist outcomes in the market for postdoctoral scholars. *Science and Public Policy, 39*, 60-73.

Weil, V. (2001). Mentoring: Some ethical considerations. *Science and Engineering Ethics*, *7*(4), 471-482.

Wennerås, C., & Wold, A. (2001). Nepotism and sexism in peer-review. In M. Wyer, M. Barbercheck, D. Cookmeyer, H. Ö. Öztürk, & M. L. Wayne (Eds.), *Women, science, and technology: a reader in feminist science studies*. New York, NY: Apex CoVantage, LLC.

White, M. S. (1970). Psychological and social barriers to women in science. *Science, 170*(3956), 413-416.

Williams, J. (2000). *Unbending gender*. New York, NY: Oxford University Press.

Winslow, S., & Davis, S. N. (2016). Gender inequality across the academic life course. *Sociology Compass*, *10*(5), 404-416.

Wolfinger, N. H., Mason, M. A., & Goulden, M. (2008). Problems in the pipeline: Gender, marriage, and fertility in the ivory tower. *The Journal of Higher Education, 79*(4), 388-405.

Wolfinger, N. H., Mason, M. A., & Goulden, M. (2009). Stay in the game: gender, family formation and alternative trajectories in the academic life course. *Social Forces, 87*(3), 1591-1621.

Wrench, J. S., & Punyanunt, N. M. (2004). Advisee-advisor communication: An exploratory study examining interpersonal communication variables in the graduate advisee-advisor relationship. *Communication Quarterly, 52*(3), 224-236.

Xu, Y. J., & Martin, C. L. (2011). Gender differences in STEM disciplines: from the aspects of informal professional networking and faculty career development. *Gender Issues, 28*, 134-154.

Zhao, C. M., Golde, C. M., & McCormick, A. C. (2007). More than a signature: How advisor choice and advisor behavior affect doctoral student satisfaction. *Journal of Further and Higher Education, 31*(3), 263-281.

Zubieta, A. F. (2009). Recognition and weak ties: is there a positive effect of postdoctoral position on academic performance and career development? *Research Evaluation, 18*(2), 105-115.