Gender, structural holes, and citations:

The effects of women's increasing proportional representation in a field

Abstract

Large, sparsely connected social networks (i.e., networks rich in "structural holes") are advantageous because they provide an informational edge. However, some studies have found that hole-rich networks can be a disadvantage for women. We examine the question: Are the returns women derive from structural holes contingent on women's changing proportional representation in a field? Focusing on the context of knowledge production, with citations as a key metric of success, we analyzed co-authorship and citation data from elite management journals (1970-2006) using panel-data regression. Our findings reveal that the number of structural holes in women's collaboration networks positively correlates with citations until women's proportion in the field reaches approximately 30 percent. Beyond this tipping point, the relationship becomes negative and significant. This result remains robust after controlling for variables such as previous citations (both the individual's and co-authors'), career stage, authorship order, gender homophily, and institutional status. Our study suggests that understanding the interplay between gender, structural holes, and citations requires a contextual perspective that considers the evolving circumstances women face as their representation in a field grows.

Keywords gender, social networks, structural holes, citations, knowledge production

Introduction

Knowledge production is a competitive affair in which the spoils go to those who can get others to cite their ideas (Merton, 1973). The collaboration network around an individual can be a potent resource in this competition. For example, prior research has found that networks rich in structural holes[1]—i.e., large, sparsely-connected networks—facilitate the generation of new ideas (e.g., Burt, 2004; Fleming, Mingo, & Chen, 2007). However, there is also evidence that hole-rich networks can be a disadvantage for women, perhaps especially in settings where women are deemed "outsiders" (Burt, 1992; Brands & Mehra, 2019; for a review of the evidence, see Woehler et al., 2021). Insider status, and the legitimacy that comes with it, is crucial for unlocking the informational edge that structural holes provide, so people deemed outsiders may be less likely to benefit from hole-rich networks than people who are deemed insiders (Burt, 1998; 2021).

A visible indicator of outsider status in a setting is low proportional representation. In her classic interview-based study of saleswomen in a Fortune 500 company, Kanter (1977) described how numerically underrepresented ("token") women faced performance scrutiny, lacked access to professional networks, and were subjected to pressure to conform to gender-stereotyped roles. From the perspective of Kanter's (1977) theory of tokenism, the experience of these women was less a function of their gender than a result of their low numbers in the setting. Number balancing, therefore, was seen as key to alleviating the negative pressures faced by women. As the proportional representation of women increases in a field, according to tokenism theory, it reaches a threshold beyond which women should confront significantly less bias.

[1] Structural holes are holes in social structure—they represent the absence of direct connections between parties connected to the same focal individual (Burt, 1992). Individuals who have large, sparsely connected personal networks have networks rich in structural holes.

A rise in proportional representation, however, may not necessarily lower barriers for women. Rarely noted is the fact that although women made up less than 10 percent of the jobs at the firm Kanter examined, their numbers had been rising sharply for a few years before Kanter interviewed the women (Yoder, 1991). When a minority group surges, this can trigger a backlash consisting of stepped-up resistance and even outright discriminatory behavior (Blalock, 1967). What the women Kanter interviewed may have experienced, therefore, is not the effects of their small numbers but, instead, the result of perceived competition provoked by their *growing* numbers (Yoder, 1991: 185). What this alternative "intrusiveness" theory suggests is that as the proportional representation of women in a field increases, bias against women strengthens rather than weakens. If legitimacy in the form of insider-status is important for women to benefit from hole-rich networks (Burt, 1998), then it is possible that women benefit less, not more, from structural holes as the proportional representation of women in a field increases.

The benefit women derive from their collaboration networks can be examined in several ways. We focus on citations because citations are the currency of science (de Solla Price, 1986). Citations are a credible indicator of the "usefulness and influence" of scientific ideas (Leahey, Beckman, and Stanko, 2017: 110). Individuals who produce a highly cited paper tend to enjoy visibility and prominence in the field and for this reason citations figure prominently in promotion and tenure decisions and influence academic salaries (Leahey, 2007; Sauer, 1988). We focus on the period between 1970 and 2006. During this period, the proportion of women academics obtaining PhDs in the field began a steady rise, from less than 5 percent in 1970 to roughly 39 percent by 2006. This increase in women's proportional representation is crucial to our investigation because it allows us to examine how the relationship between structural holes and citations changes as the proportion of women in the field increases.

We seek to contribute to the ongoing discussion about the role of legitimacy in the benefits women derive from their social networks (e.g., Burt, 1992, 1998; Brands and Mehra, 2019). Academia is a particularly appealing setting for this exploration because it is an occupational realm where "true inclusion is treasured—and jealously guarded" (Gersick, Bartunek, & Dutton, 2000: 1032). It is also a domain where professional relationships influence both the ideas one comes up with and the reputational status one's ideas acquire (Merton, 1973; Collins, 1998). Our study complements existing research on the effects of structural holes on knowledge production by focusing on the use of knowledge in the field *after* the knowledge has been produced (cf. Fleming, Ming, and Chen, 2007). We contribute fresh ideas and new evidence to the emerging contextual approach to understanding gender-based differences in network returns (e.g., Joshi et al., 2015; Lampronti, Operti, and Sgourev, 2024)

Our overarching goal is to use quantitative data and methods to help reconcile competing theoretical perspectives and potentially discover unexpected patterns. Rather than formulating a formal hypothesis, we engage in a form of abductive reasoning (see Bamberger & Ang, 2016). We investigate whether the kind of network that helps women produce scientific ideas that are subsequently used in the field changes as the legitimacy of women in the field changes. To foreshadow a key result, we find that this change can be discontinuous: structural holes shift from being an advantage to a disadvantage once a tipping point[2] in women's proportional representation in the field is reached.

The network advantage in science

[2] Our use of the term "tipping point" is based on Kanter's (1977) usage. Drawing inspiration from Georg Simmel's (1950) classic analysis of the significance of numbers in social life, Kanter (1977) argued that when a critical mass of women in a setting is reached, this can precipitate fundamental shifts in an organization's culture and gender dynamics. In our paper, the term "tipping point" indicates the proportion of women in the field beyond which the relationship between structural holes and citations shifted in direction, from positive to negative. For a discussion of the different ways tipping points have been conceived in the broader scientific literature, see, e.g., Dakos et al., 2024; Lamberson and Page, 2012; van Nes et al., 2016.

Science is a social enterprise, embedded in shared understandings of the world that come to define what constitutes valid and useful thinking (Kuhn, 1962). New ideas, which necessarily fall at the boundaries of these common understandings, are difficult for actors to assess.

To generate new knowledge that others in the field cite, the right collaboration network can be an advantage for several reasons. Knowledge producers are embedded in social networks used to exchange ideas and keep track of the growth of knowledge in a field (e.g., Crane, 1977). These networks can be an informational resource, providing early access to a broad array of ideas and techniques that are not yet in the mainstream and are difficult or costly to acquire independently, such as expert feedback on research ideas, technical help with methods and analysis, and knowledge of research being conducted by others (Bagilhole and Goode, 2001).

Beyond the information-based resources that collaboration networks provide, network connections can help because they are a resource for identity construction and image projection. A scholar's collaboration network is a source of role expectations and conveys a sense of belonging, helping the individual construct a sense of professional identity (Podolny & Baron, 1997). Moreover, the collaboration network around an individual is a potent signal to *others* in the field of the individual's professional identity (e.g., Halgin et al. 2020). Given the ambiguity of quality, consumers of new knowledge look for cues to help them decide what new knowledge is worth attending to and citing. One cue that individuals are likely to attend to is the collaboration network around the producer. Networks function as prisms, conferring identity and signaling reputations to observers (Podolny, 2001). In academia, a scholar's collaboration network is crucial for building his or her professional reputation (Brink and Benschop, 2011; Gersick, Bartunek, and Dutton, 2000). The collaboration networks that are revealed through co-publications in a field's top journals are the visible layer of the more extensive but harder to discern "personal invisible college"[3] around individual knowledge producers (Mullins, 1973: 18). Consequently, scholars look to the collaboration network around an individual for cues about the underlying identity of the person as a scholar and the quality and usefulness of the knowledge produced by that individual (Crane, 1977; Merton, 1973).

Gender, structural holes, and citations

Although network indicators of quality should be valuable to anyone, they are likely to be especially important for women in academia. Academia is a male-typed profession (Brink and Benschop, 2011, 2014). Excellence in academia is typically defined in a manner that emphasizes individualism and self-promotion (Brink and Benschop, 2011), traits that are stereotypically associated with men not women (Ellemers, 2018). The structure of the personal collaboration network, and the associated identity construction and identity conferral processes, therefore, is likely to particularly affect evaluations and subsequent citation of women's work. This is because the structure of interpersonal connections around a knowledge producer provides role expectations and a sense of support and belonging that shape an individual's professional identity. It also provides clues to others about the identity of the work produced by that individual and whether it is worth citing. In the context of science, a collaboration network of co-authors who have co-authored with each other indicates a set of scholars who adopt each other's ideas, study similar topics, and use similar techniques (Moody, 2004). Interconnected networks may be necessary for the development and projection of a clear scholarly identity (Podolny and Baron, 1997) and, therefore, the accrual of citations.

[3] D.J. de Solla Price (1961) adopted the term "invisible college" from Robert Boyle. In its sociological formulation, the term signifies the social structure defined by interconnections between the members of a scientific field, interconnections that correspond also to the "cognitive structure of the field" (Merton, 1973: 6). The "personal invisible college," in Mullin's (1973) usage, refers to the personal network of individual scientists within a broader field.

Because the quality of new scientific papers can be ambiguous, and because most people only read a small fraction of the volume of new papers in a field, it is plausible that people look for a clear signal of identity in deciding which papers to attend to and subsequently cite. Collaboration networks with few structural holes, provide such a signal. Interconnected scientific collaboration networks help convey a clear identity by signaling inclusion in a network of scholars. By contrast, a woman whose collaboration network bridges the structural holes between many different scholars is likely to be subject to inconsistent role expectations making it harder for her to construct and project a clear, readily categorized professional identity. Networks rich in structural holes are a poor resource for personal identity construction and do little to mitigate observers' concerns about the underlying quality of a woman's scholarship; indeed, it may exacerbate such concerns. Hole-rich networks, therefore, may dampen citations to women's scholarship.

Brokerage, moreover, is a stereotypically masculine network structure. Empirical research has found that individuals (both men and women) expect men (not women) to have networks rich in structural holes (Brands and Kilduff, 2013). Moreover, women tend to experience a lowered sense of self-efficacy when they perceive their networks as disconnected, resulting in lowered performance (Brands and Mehra, 2019). Women who have brokerage collaboration networks (i.e., networks that are rich in structural holes) may doubly provoke negative expectations because they both work in a male-typed profession and occupy a male-typed network (see Brands and Mehra, 2019 on the male-typing of brokerage networks). These negative expectations, borne out of gender stereotypes about the kinds of networks that are appropriate for women/men, could lead to the devaluation of women's work and reduce citations to women's papers.

The plausibility of these arguments notwithstanding, empirical evidence on gender differences in returns to structural holes has been sparse and inconsistent (Woehler et al., 2021). Whereas some studies have found that women fail to benefit from networks rich in structural holes (e.g., Burt, 1998; Brands & Mehra, 2019), others have found no gender differences in returns to structural holes (e.g., Brass, 1985; Burt & Opper, 2017; Jadidi et al., 2018; Lutter, 2015).

Effects of Changing Proportional Representation

Burt (1998) argues that women fail to benefit from structural holes in settings where they lack legitimacy and are seen as relative outsiders. In corporate settings, for example, it is not just women but entry-level men who fail to benefit from structural holes (Burt, 1992), suggesting that poor returns to brokerage are more a function of "outsider" status (Merton, 1973) than of gender per se (Burt, 1998; Burt & Opper, 2017). From this perspective, in settings where women enjoy insider status, there should be no gender differences in returns to structural holes.

There are a range of factors that can determine relative status in a field. Kanter's theory of tokenism (1977) emphasizes relative numbers as key. In her classic study of saleswomen working for a large multinational firm, Kanter argued that women's numeric underrepresentation consigned them to "token" status. Token women faced three challenges. First, although they stood out as women, they were largely invisible as individuals—the attention token women received more often focused on irrelevant characteristics (such as physical appearance) rather than on performance-relevant characteristics (Kanter, 1977). Second, women's differences from their male peers were exaggerated. Third, women were consigned to gender-stereotyped roles. In the decades since Kanter's classic work was published, her findings have been replicated across a range of settings, including the military, medicine, law, and business (Yoder, 1991). Kanter (1977) argued that the negative experiences of the women she studied were the result of skewed gender proportions. If women were present in greater numbers, they might have avoided the challenges they faced as tokens.

A rise in the relative numbers of a minority group, however, may not necessarily ameliorate their status as relative outsiders. It could even have the opposite effect. When the numbers of a minority group surge, members of the majority group may worry about growing competition for resources and perceive it as a threat to their power, resulting in greater bias towards members of the minority group (Blalock, 1967). There is some empirical support (e.g., South et al., 1982; Frisbie & Neidert, 1977) for the ideas that surges in minority numbers are interpreted as a threat by the majority group, which then responds with heightened levels of bias (as observable in pay inequities, lack of support, and delayed promotions) towards members of the minority group. Flows of people deemed outsiders into a field can provoke a backlash (Laws, 1975).

In the setting Kanter examined, women comprised a small percentage (10%) of salaried job holders, but their numbers had surged (by 50 percent) from a few years earlier (Kanter, 1977: 206). Kanter (1977: 986) speculated that there may be a "tipping point," a critical threshold, in women's proportional representation beyond which the negative effects of tokenism would dissipate. But, from the contrasting perspective of Blalock's (1967) intrusiveness theory, "Kanter's saleswomen may have felt the negative effects not of their small numbers but of their increasing numbers" (Yoder, 1991: 185).

What, then, are the implications of Kanter's (1977) and Blalock's (1967) theories for the kinds of networks that are likely to be associated with women's success in the production of influential ideas? From the perspective of tokenism theory, when women are numerically underrepresented, they face the problem of invisibility—they struggle to be seen as credible occupants of their professional role. This lack of credibility should make it difficult for women to benefit from hole-rich networks when there are very few of them. But as the proportion of women in the field rises, they are likely to gain in status and credibility, allowing them to benefit from hole-rich networks. From the perspective of intrusiveness theory, we can expect the opposite: as women's relative numbers increase, they should be more likely to be viewed as outsiders who pose a threat to the status quo. Under these conditions, it should be interconnected networks, not those rich in structural holes, that benefit women. Given these plausible but competing conjectures, we follow the logic of abductive reasoning by refraining from formal hypothesis testing and instead engage in a form of quantitative discovery (Bamberger & Ang, 2016). The core question we examine is: *Are the returns (in the form of citations, an indicator of scientific influence) that women scholars derive from structural holes in their collaboration networks contingent on their changing proportional representation in the field?*

Methods

Sample and procedure

The literature has frequently relied on co-authorship data to capture the collaboration networks around knowledge producers (e.g., McFadyen and Cannella Jr, 2004). Our study draws on longitudinal data on patterns of co-authorship among men and women who published at least one article in what are widely considered to be elite journals in the field of management: *Academy of Management Journal, Academy of Management Review, Administrative Science Quarterly, Organization Science,* and *Strategic Management Journal.* This is, of course, a small subset of management journals. We purposefully selected what are arguably the most prestigious and broadly visible journals in the field of management. Authorship ties in these journals require significant interaction and resource exchange and are widely noticed and discussed by others in the field of management. A key indicator of the enduring prestige and visibility of these journals is their inclusion in the UT Dallas journal rankings: https://jsom.utdallas.edu/the-utd-top-100-business-school-research-rankings/.

To enhance accuracy and comprehensiveness, we collected publication data from two reliable online databases: Web of Science and EBSCOHost (Business Source Complete). The total number of records obtained from the Web of Science was 8,554, including articles, editorial materials, book reviews, notes, and corrections. We dropped all material except published articles from consideration, which left us with 5,290 articles. The total number of records collected from Business Source Premier was 6,963, of which 5413 were articles. We matched the two databases by the journal name, volume, issue, and beginning page. When this information was missing or inconsistent, we matched articles across the two databases using the title of the article. For overlapping time periods (e.g., Academy of Management Journal, 1983-2006), the two databases were matched by assigning paper identification numbers to ensure data accuracy. The final number of articles used in this study was 5,602.

We assigned each author a unique identification number. Author names were decomposed into last name, first name, and middle name. If all parts of two authors' names were identical, the same identification number was assigned. Some authors had slightly different variations of their name across publications (e.g., middle name was sometimes included, abbreviated, or omitted). A rater who was blind to our research question checked these names by searching the authors' affiliation information and online profiles to determine if the slightly different variations of a name represented the same author. Otherwise, we assigned a new identification number to the individual. The final number of distinct authors was 3,888 (of whom 941 were women). We constructed a person-year panel such that each data point (i, t) in the panel representing the person i published a paper in year t in at least one of our focal journals. Thus, our unit of analysis is the person-year.

We constructed the social network in year t using collaborations in the previous five years – that is, we consider person i and person j as connected in year t if they co-authored at least one paper in the five focal journals between year t-5 and year t-1. This means the social network around an individual can vary over time. Network variables were computed with the social network analysis software package UCINET VI (Borgatti, Everett, and Freeman, 2002).

Measures

Citations. To measure the "usefulness and influence" of a person's knowledge production, we first identified the publications that the person produced from t through t+4. We then turned to the Web of Science to collect data on how many times these publications were cited. Unlike authorship, we did not restrict citations to just five elite journals; we counted all citations from the Web of Science, irrespective of which journal the citation occurred in. All citations in this study are defined as *five-year citations*, i.e., the number of citations a paper received within five years of its publication. We used a five-year citation window because citations to most articles tend to peak five years after initial publication (Judge et al., 2007). *Administrative Science Quarterly*, one of the journals in our database, uses the same five-year window when selecting recipients of their most impactful article award. Moreover, there is precedent for using five-year time windows in assessing co-authorship network ties (e.g., McFadyen and Cannella Jr, 2004; Moody, 2004), suggesting that the length of our citation window is reasonable.

Gender. Because information on gender is not explicitly included in the Web of Science or EBSCO, we took three steps to identify an author's gender. First, we used a computer program, written in the web-programming language PHP, to automatically query the gender of all names against an online database "Behind the Name" (http://www.behindthename.com). Behind the Name provides information on the etymology, meaning, and gender of given names in multiple cultures (e.g., English, French, Indian, Arabic). The website has been used in a number of name-related studies (e.g., Vick and Huynh, 2011) and a review article noted that the website was more reliable and comprehensive than other popular databases, such as Babynames.com and BabyCenter.com (Lindsay, 2001). The PHP program matched author first names with Behind the Name entries and extracted the gender information. The program automatically assigned a gender to a name only when the website returned an exclusive gender "F" or "M". There were 539 "F" and 2,051 "M". The program allowed us to reliably code gender for 2,590 authors, representing 67% of our sample. Next, for authors whose gender has not been identified in step 1, we searched through the short author biographies that accompanied published articles for language (the use of "he" versus "she") to code gender for an additional 995 authors. Third, if the gender of an individual was still unclear, we conducted detailed online searches to locate information to help us code gender (e.g., online web pages and profiles). This three-step process resulted in the coding of gender for all the authors in our final sample of 3,889 individuals, 941 (24.2%) of whom were women. Gender was coded as a dichotomous variable (1 = women, 0 = men).

Structural holes. An individual's network is rich in structural holes if the individual is connected to many people who are not themselves connected. A person's structural holes at time *t* were constructed from co-authorships over the previous 5 years. Consistent with recent empirical research on structural holes (Cummings and Cross, 2003; Shipilov, 2009; Gray, Parise, and Iyer, 2011), we used the "effective size" measure to assess the number of structural holes in a person's network (see Burt, 1992: 52 for the formula). Effective size computes the number of co-authors in an author's co-authorship network minus the average number of ties among co-authors (Borgatti, 1997). Higher values indicate more structural holes. We found that the variable effective size was left-skewed, creating the potential for overly-influential observations. Negative binomial regression is robust to skewness in variables, so addressing skewness is not strictly necessary. Nonetheless, we log-transformed effective size (log (effective size + 1)) to improve the model's interpretability and fit, reduce the impact of influential observations, and minimize the threat of multicollinearity. The pattern of results was the same irrespective of whether we used effective size or log transformed effective size.

Proportion of Women PhDs. We obtained data from the AACSB on the percentage of PhDs granted business degrees in a focal year by women and men. This variable increased from less than 5 percent in 1970 to 39 percent by 2006.

Years since PhD. A person's citations are likely influenced by the person's career stage (de Solla Price, 1986). To capture this, we introduced a variable called *Years since PhD*, defined as the number of years since the person received his or her PhD. To calculate this variable, we obtained dissertation information through the database, ProQuest. Using the name-matching process described above, we were able to get information on the year a scholar had received the PhD for 2,276 out of 3,888 authors (58.54% of our sample). We manually searched the online profiles of the remaining 1,613 authors. We entered names into the Google web search engine and accessed their personal/university web pages or online *curricula vitae* to obtain the information on the years they received PhDs. Using this approach, we obtained 958 additional records on *Years since PhD*. We did not find personal/university web pages or online *curricula vitae* for the remaining 654 authors. We therefore had data for the year the PhD was received for a total of 3,234 authors. Because we were missing data on this variable for 654 individuals, we used the mean replacement method to preserve these cases in our analyses (Roth, 1994).

Prior citations. An individual's past performance is likely to influence the person's subsequent collaboration network (Lee, 2010) and future citations. We measured *prior citations* of an author at year *t* as the number of (five-year) citations to the author's publications in the previous five years (i.e., t-5 to t-1).

First authorship. Different fields have different norms for deciding the order of authorship on jointly produced papers. In the field of management, first authorship is typically interpreted as a signal that the person was the leading contributor on the paper. To account for the possible effects of authorship order, we included as a control the number of papers an author published during the period t-5 to t-1 in the role of first author.

Last authorship. To account for the possibility that playing the role of last author may influence citations, we computed the number of papers an author published during the period t-5 to t-1 where they were the last author of the paper and included this measure as a control variable in our analyses.

Current institution's citations. The status of a university where a person is located is likely to influence subsequent citations to that person's work. The status of the university can be a powerful signal to audiences about the underlying quality of the work produced (Ilgen, 2007; Judge, et al., 2007). Moreover, high-status universities are likely to include faculty who can serve as informal guides and mentors even if they do not co-author with the person. We measured the status of the university using the university's past publications and citations. Specifically, we firstly calculated the total number of publications in the five focal journals by authors affiliated with the university from 1970 to t-1. We then measured five-year citations to these publications. We turned to the Web of Science and EBSCOHost to gather data on an author's university affiliation at the time of publication. We assigned each university a unique identification code. 3,270 authors' affiliation information was identified (84.08% of our sample). Affiliation data were missing for 619 cases; we used the mean replacement method to preserve these cases in our analyses (Roth, 1994). A dummy variable for missing affiliation data was included in the analyses.

Graduate institution's citations. The status of the university where a person earned the Ph.D. degree can be expected to impact the attention that the person's published research receives. To account for this, we included as a control a measure of the status of the university that granted the person the Ph.D. degree: *graduate institution's citations.* This variable was measured by computing the total number of citations by the university where a person received their Ph.D. in the top five management journals from 1970 to t-1.

Co-author citations. Our theory focuses on the effects of network structure, not network composition. But it is, of course, possible that who one is connected to makes a difference to whether the ideas one produces are subsequently cited (Merton, 1968). A key compositional characteristic we sought to control for was the extent to which the people in an individual's network were themselves well-cited. We assessed *co-author citations* by counting the total citations to papers published by an individual's co-authors from t-5 to t-1.

Isolates. Although co-authored articles made up the vast majority of our sample, there were 357 cases in which all the papers a person published from 1970 to t-1 were sole authored. In addition, 2,519 people did not have co-authors in a given five-year window (t-5 to t-1). We coded this variable as 1 if the person was an isolate and as 0 otherwise, and we included it as a control in our baseline regression models. However, the personal network of an isolate is a special kind of structure. Effective size can be formulated as network size minus the average degree of alters (Borgatti, 1997), which in the case of isolates is mathematically undefined. As a result, our main analyses exclude isolates whenever effective size was also in the model. However, we also report below that we found similar results when we ran alternative analyses that treated effective size as zero for isolates and then added the isolate variable to all models.

The Appendix offers a summary of key study variables and their measurement.

Analyses

Our analyses employed panel data regression because our data contain multiple observations for each individual at different time periods (Arellano, 2003; Hsiao, 2007).

Given that our dependent variable represents a count, negative binomial regressions for panel data were used for statistical analyses. We used the random-effects model with person as the grouping variable to test our hypotheses, which is consistent with previous research (e.g., Ahuja, 2000; Greve, 2003; Wu, Levitas, and Priem, 2005). The random-effects model was used because fixed-effects models do not allow for the inclusion of person-level time-invariant variables, such as gender, a variable that is key to our investigation. Although not shown in the tables, all models included dummy variables for 5-year time periods.

Results

Table 1 presents means, standard deviations, and correlations. In the five-year periods, the mean number of papers published by an individual in our sample was 2.07 (*SD* = 1.65) and the mean number of citations an individual received was 36.19 (*SD* = 47.14).

INSERT TABLE 1 HERE

We begin by examining the straightforward question: are women less likely than men to benefit from structural holes? Model 1 in Table 2 shows the effects of regressing citations on our control variables. Each of the control variables explained significant variance in our dependent variable. Model 2 shows that, accounting for the effects of our control variables, gender was a significant predictor of citations: women's papers were significantly more likely to be cited than men's papers (β = .12, p = .00). Model 3 shows that structural holes in an individual's network were not a significant predictor of subsequent citations (β = .01, p = .89). Model 4 adds the interaction term between gender and effective size to the regression model containing the control variables, gender, and effective size. The parameter estimate for the interaction term is statistically significant (β = -.24, p = .00). A plot of the interaction (Figure 1) shows that the slope of the line for women is negative and significant (β = -.20, p = .01) whereas the slope of the line for men is not significant (β = .04, p = .27). These results indicate that collaboration networks rich in structural holes are disadvantageous for women when it comes to having their work cited in the field.

INSERT TABLE 2 and FIGURE 1 HERE

What happens to the relationship between hole-rich networks, gender, and citations as the proportional representation of women in a field increase? Model 5 in Table 2 presents the regression of the first-order terms on citations. Model 6 in Table 2 presents the regression of the hypothesized three-way interaction with all the required second-order interactions included in the model. The parameter estimate for the three-way interaction term is statistically significant (β = -5.69, p = .00).

INSERT FIGURES 2A and 2B HERE

To examine the form of this three-way interaction, we split the sample by gender and examined the interactive effects of the structural holes in a person's network and the legitimacy of women in the field on subsequent citations. Figure 2a shows the plot of the relationship between the number of structural holes in an individual's co-authorship network, the percentage of women who received a PhD in the field, and subsequent citations for men. The slope of the line representing the relationship between structural holes and citations to men when the percentage of women in the field was high (+2 *SD* from the mean) is negative (β = -.03, p = .68) while the slope of the line representing the relationship between structural holes and citations to men when the percentage of women in the field was low (-2 *SD* from the mean) is positive (β = .13, p = .14). Figure 2b plots these same relationships for women. The slope of the line representing the relationship between the number of structural holes in a woman's network and the number of subsequent citations the woman received when the percentage of women in the field was high is negative (β = -.78, p = .00). By contrast, the slope of the line representing the same relationship when the percentage of women in the field was low is positive (*β* = 1.06, *p* = .00). The regression results considered together with the interpretations of the graphed results show that when the numeric proportions of women in the field was low, women benefited from networks rich in structural holes. By contrast, when women's numeric representation was relatively high, they were more likely to benefit from interconnected networks lacking structural holes.

INSERT TABLE 3 HERE

If collaboration networks rich in structural holes are valuable for women when there are relatively few women in the field and networks with few structural holes (i.e., interconnected networks) are valuable for women when there are relatively more women in the field, the question arises: At what point do structural holes switch from being an asset for women to becoming a deficit? To find the answer to this question, we conducted a Johnson-Neyman floodlight analysis (Johnson and Neyman, 1936; Spiller et al., 2013) that examined the significance of the parameter representing the effects of structural holes on citations to women at different values of the variable representing women's proportional representation in the field. Floodlight analysis can be used to identify ranges of values where women's proportional representation has a positive impact of effective size on women's citations, where this impact is statistically significant, and where the direction of the effect switches (see Krishna, 2016). As shown in Table 3, the parameter representing the effects of effective size on citations is significant and positive up to the point where women make up roughly 25 percent of Ph.D. recipients in the field; it is insignificant between 25 percent and 30 percent; and it is significant and negative once women comprise more than 30 percent of the field. This shows that, when it comes to citations to women's work, structural holes go from being a benefit to a drawback as women’s proportional representation in the field approaches 30 percent.

Auxiliary Analyses and Robustness Checks

We examined the sensitivity of our results to the size of the time windows used to construct our network measure, and our dependent variable, citations. We obtained the same pattern of results when we used four-year windows and six-year windows as we did when we used five-year windows. For four-year windows, the parameter estimate for the three-way interaction between gender, percentage of women PhDs, and structural holes was statistically significant (β = -3.66, p = .00); and, for six-year windows, the parameter estimate for the three-way interaction between gender, percentage of women PhDs, and structural holes was also statistically significant (β = -3.77, p = .00).

We used the number of women receiving PhDs in the field as a structural indicator of women’s legitimacy. To check the reliability of our results, we computed an alternative measure of women’s legitimacy in the field: the proportion of editorial board positions held by women in the five journals we examined. We obtained the same pattern of results as reported in Table 2 when we used this alternative measure of women’s legitimacy in the field (regression coefficient for the three-way interaction between gender, percentage of women PhDs, and structural holes was β = -8.54, p = .00).

In our main analysis we treated the effective size of isolates as undefined, which meant we could not simultaneously include the “isolates” variable as a control. However, we did run alternative models that assigned a zero as the effective size for isolates and used its log-transformed form. This approach yielded a similar pattern of results: women benefited from having more structural holes when there were relatively few women in the field, but they benefited from having fewer structural holes when there were relatively more women in the field (β = -1.74, p = .01).

We checked to see if our results were robust to the inclusion of data from earlier years (starting in 1956, when the journal Administrative Science Quarterly was launched). During these early years, we have more missing data for some of our control variables, and the number of women publishing in top journals was quite small until about 1970. An increase in women's proportional representation is key to testing our theory, so starting the sample in 1970 is appropriate. Nonetheless, we checked to confirm that the inclusion of this early year data did not change the pattern of results. We again found that women benefited less from structural holes relative to men (β = -.24, p = .00); and women benefited from structural holes when there were relatively few women in the field, but they benefited from interconnected networks when there were relatively more women in the field (β = -5.69, p = .00).

Because we are interested in how new ideas are subsequently used by others, we have focused on citations as our dependent variable. In supplementary analyses, we re-ran the regression models in Table 2 using the number of new papers published in the same set of elite management journals over a five-year window as our dependent variable. We found that the presence of structural holes in collaboration networks was a positive and significant predictor of the number of new papers published (β = .09, p = .09), but there was no support for the idea that these effects of structural holes were contingent on gender (β = -.12, p = .43) and/or the proportion of women PhDs in the field (β = .88, p = .69). These findings suggest that the contingent effects of gender and proportional representation matter for certain classes of network-based advantage (citations) but not for others (production of new ideas).

Is it possible that what matters for citations is who women are collaborating with rather than the structure of women's collaboration networks? In auxiliary analyses, we found that women and men did not differ significantly in the extent to which they benefited from ties to highly cited individuals (β = -.0004, p = .01). There was also no support for the three-way interaction between gender, co-authors' citations, and our measure of women's proportional representation (β = -.004, p = .38). Moreover, controlling for the degree of gender-based homophily present in a woman's network (i.e., the extent to which a network was composed of same-gender others) did not significantly change the effects of structural holes in a woman's network on subsequent citations (β = -.26, p = .00). It was the structure of the network, not the characteristics of the people in it, that mattered when it came to gender-based differences in network-effects on citations.

Discussion

Collaboration networks rich in structural holes are useful for producing good ideas (e.g., Burt, 2004; Fleming, Mingo, & Chen, 2007; for a review, see Burt, 2021). However, theory and evidence are mixed as to whether women benefit from hole-rich networks (Burt, 1998; Brands & Mehra, 2019; for a review, see Woehler et al., 2021). More generally, it is puzzling why minority group members fail to reap the same benefits as majority group members even when they possess similar social networks (Khattab et al., 2020). In this paper, we examined this question from a dynamic perspective, attentive to the possibility that structural holes may be an advantage or a disadvantage for women contingent on women's *changing* numeric proportions in the field.

We used co-authorship and citation data from elite journals in the field of management between 1970 and 2006 to sift between two contrasting theory-based expectations. From the perspective of Kanter's (1977) theory of tokenism, as the proportion of women in a field increases, so does their legitimacy. From a socio-cognitive perspective, legitimacy is a perception or evaluation of the extent to which an actor matches a cognitive category or social identity—e.g., that of a scientist (Suddaby, Bitektine, and Haack, 2017). As the number of women in the field grows, the prototype of a business academic changes in ways that allow more women to be recognized as fully legitimate members of the field– i.e., as insiders. Network scholars have argued that legitimacy is a key prerequisite for benefiting from structural holes (Burt, 1998). Audience uncertainty about a would-be broker limits the ability of the broker to harness the informational breadth, timing, and arbitrage advantages of structural holes (Burt, 2021; Rider, 2009). This implies that as the proportion of women in a field increases women should benefit *more* from collaboration networks rich in structural holes. From the contrasting perspective of Blalock's (1967) theory of intrusiveness, however, as the relative proportion of women in the field increases, the sense that women are not fully legitimate grows rather than weakens. Blalock's theory, therefore, leads to the opposite prediction: As the proportion of women in a field rises women should benefit *less* from collaboration networks rich in structural holes.

Given these competing yet plausible theories, we eschewed a priori hypotheses and instead adopted an abductive approach emphasizing quantitative discovery (Bamberger & Ang, 2016). Panel-data regression analysis of co-authorship and citation data showed support for the Blalockian perspective: Women benefited more from structural holes when they comprised a smaller proportion of the field. We discovered, moreover, what appears to be a tipping point: as the proportional representation of women in the field reached roughly 30 percent, structural holes turned from an advantage (measured as citations) to a disadvantage for women.[4]

Implications and contributions

There is renewed interest in understanding how ascribed characteristics, such as gender, shape the benefits individuals derive from their social networks (e.g., Brands, Ertug, Fonti, & Tasselli, 2022; Khattab, van Knippenberg, Pieterse, and Hernandez, 2020). The question of whether and how women benefit from increasing proportional representation has been the subject of previous work (e.g., Mackey et al. 2019). However, as noted in a recent

[4] It is noteworthy that this figure of 30 percent is close to the 35 percent figure Kanter (1977: 966) speculated may be "a tipping point" (p.986) beyond which the majority group loses its dominance, no longer controlling the group and dictating its culture.

review (Woehler et al., 2021), there is little clarity in the literature regarding whether and why gender influences the benefits people derive from specific network characteristics. Consider the literature on structural holes: scholars have identified that women often derive less benefit and may even be harmed in terms of their performance and reputation by spanning structural holes. A range of explanations have been offered for this finding, but the focus has been on individual level explanations, such as women's networking behaviors. or others' stereotyping of women who span structural holes (see Brands et al., 2022). We contribute to this discussion by focusing on a contextual feature which may shape women's returns to network brokerage: women's proportional representation in the field. Analyses revealed that gender-based differences in the effects of structural holes varied as a function of women's changing proportional representation in the field. We found that networks rich in structural holes were disadvantageous for women—but only when there were relatively many rather than relatively few women in the field.

We have used Blalock's (1967) theory of intrusiveness to suggest that as the number of women in the field began to rise, this may have, somewhat counterintuitively, contributed to the sense that women were outsiders lacking full legitimacy. Under these conditions, structural holes can be a drawback rather than an asset for women because legitimacy is key to unlocking the benefits of structural holes. It is possible that when women were present in proportionally small numbers in the field, the primary challenge they faced was that of invisibility. As Kanter (1977) noted, when present in small proportions, tokens are rendered invisible in the sense that they are confused with one another and the attention that is paid to them focuses more often on performance-irrelevant characteristics. Attention from others in a field is a necessary precondition for the evaluation and use of new knowledge. Women with collaboration networks rich in structural holes may garner greater attention in the field than women with closed collaboration networks. Individuals whose co-authorship networks make them a bridge between other individuals have, by definition, a larger, more diverse audience for their work than individuals with few structural holes (Fleming, Mingo, & Chen, 2007; Leahey, Beckman, and Stanko, 2017). This attention-garnering effect of structural holes may be particularly strong for women because people stereotypically expect women's networks to be interconnected and dense rather than sparse and full of structural holes (Brands and Kilduff, 2013). Individuals pay more attention to people whose behavior or characteristics render them counter-normative (Stroessner, 1996). This means that hole-rich collaboration networks may help women garner greater attention in the field; and this attention, which is limited and at a premium in scientific fields (Collins, 1998), can enhance citations.

Blalock's (1967) theory anticipates that as the proportion of women in a field increases, the primary challenge faced by women academics shifts from invisibility to stepped up bias. Under such conditions, a clear identity signaled by inclusion in a group of scholars can help allay concerns about the underlying quality of a woman's work. Moreover, closed networks (relative to open networks rich in structural holes) provide an individual with greater social support (Coleman, 1988), which can be a key resource for women combating gender-bias (Gersick, Bartunek, and Dutton, 2000; Ody-Brasier and Fernandez-Mateo, 2017). Because networks rich in structural holes are poor at allaying concerns about professional identity (Podolny and Baron, 1997) and provide relatively little social support (Coleman, 1988), this may explain why women benefited from the absence of structural holes as the proportional representation of women in the field grew.

If networks rich in structural holes are valuable for women when there are relatively few women in the field and closed networks are valuable for women when there are relatively more women in the field, the question arises: at what point do structural holes switch from being an asset for women seeking to have their new ideas used in the field (as reflected in citations) to becoming a deficit? We found that the parameter for our measure of structural holes was significant and positive up to the point where women made up roughly 25 percent of PhD recipients; it was insignificant between 25 percent and 30 percent; and it was significant and negative once women make up more than 30 percent. These results are broadly consistent with the argument that when present in small proportions women face the challenge of cognitive invisibility, and structural holes help women meet this challenge. But, as their relative numbers rise, the bigger challenge women face may be stepped-up bias (e.g., South et al., 1982). When minorities surge and come to be represented in proportionally larger numbers in a field, this can provoke a sense among members of the dominant group that minority group members are "taking over" their turf (Blalock, 1967; Yoder, 1991: 188).

Our research design does not allow us to directly observe the bias that women faced, nor can it offer any definitive evidence of what provoked the bias. However, there is some evidence from other settings, such as law schools, that is consistent with the idea that as the numbers of tokens surge in a field, the perceptual challenge of invisibility created by small numbers is supplanted by the challenge of bias triggered by a sense of growing intrusiveness (e.g., Epstein, 1981). Similarly, there is rich qualitative evidence of heightened gender bias in reports about the field of management from around the turn of the century (Gersick, Bartunek, and Dutton, 2000), the very period when the proportion of women receiving PhDs in the field approached the tipping point (Kanter, 1977: 987) our analyses uncovered. Future research in this line of work may have to toggle back and forth between field settings and laboratory-based settings to more definitively establish how changes in proportional representation first lead to invisibility and then later provoke bias.

Organizational studies of the gender-contingent effects of structural holes have focused on such outcomes as performance (Brands & Mehra, 2019) and speed of promotions (Burt, 1998). The focus of our study, by contrast, was citations, which arguably better reflect not the production of new ideas but their subsequent use. There is some prior evidence that whereas collaboration networks rich in structural holes are valuable for the generation of new ideas, ideas that are generated in hole-rich networks are less likely to be subsequently used/cited (Fleming, Mingo, & Chen, 2007). Recall that in supplementary analyses we found that the presence of structural holes in collaboration networks facilitated the subsequent production of new papers, but this effect was contingent neither on gender nor on the proportion of women in the field. Numeric proportions mattered for certain types of advantage (citations) but not for others (production of new ideas). Future research should more carefully examine why the network effects we have observed vary for different types of advantage.

Prior work suggests that who one is connected to, rather than the structure of a person's network, can help people find an audience for new ideas (Podolny, 2001). Connections to high-status others can help ameliorate the uncertainty about the quality of that individual (Podolny, 2001), so individuals connected to high-status others receive a reputational boost from their network connections (Kilduff and Krackhardt, 1994). We failed to find support for this idea (as reported in the section on Auxiliary analyses): Women and men did not differ significantly in the extent to which they benefited from ties to highly cited individuals, a credible measure of informal status in academia (Merton, 1973). And controlling for the degree of gender-based homophily present in a woman's network did not change the significant effects of the interaction between structural holes in a woman's network, gender, and our measure of women's representation in the field on subsequent citations. It was network structure, not network composition, that mattered for explaining gender-based differences in network-effects.

Limitations and future research

Our study relied on co-authorship data to construct the collaboration networks around knowledge producers. The merit of this approach is that it allowed us to study social networks for thousands of individuals over a period spanning decades. Alternative approaches that rely on individuals to directly report their social network ties would have allowed us to better distinguish the quality of ties among individuals—working together on scientific papers may lead individuals to trust and respect one another; but it is also possible that this intense collaborative work results in distrust, animosity, or lack of respect. Our design does not allow us to account for such microscopic distinctions regarding tie-content, and yet such distinctions, as relationally oriented network researchers have noted (e.g., Lin, 2008; Podolny & Baron, 1997) may be important for understanding how new knowledge comes to be cited in the field. A broader limitation is that a lot of network effects go on before people come together to successfully co-author an elite publication, and these effects we cannot assess. By restricting our attention to co-authorship in elite journals, we are missing many other significant social interactions that may influence variance in citations that an individual's work receives. Future work could attempt to supplement co-authorship data with self-report or other credible measures of interpersonal collaboration.

Citations were counted irrespective of the journal doing the citing. However, when constructing co-authorship networks, we restricted our focus to publications in elite management journals. This was a deliberate strategy. Our assumption is that papers, and co-authorships, that appear in elite journals are especially likely to be noticed and influence the receipt of citations. However, it is possible that citations are also influenced by co-authorships in less prominent journals. Future work can examine whether the gender-contingent value of structural holes only apply when the focus is on elite collaborations or extend to collaborations more generally.

We focused on the period between 1970 and 2006 because it was during this period that the proportion of women academics obtaining PhDs in the field steadily increased, from less than 5 percent in 1970 to roughly 39 percent by 2006, where it has since largely plateaued (see, e.g., https://ncses.nsf.gov/pubs/nsf20301/data-tables/#top). Moreover, the advent of readily available online databases and search engines over the last two decades may have shaped patterns of citations in new and unexpected ways. It is unclear what the relationship between structural holes and citations to women will look like in the years after 2006. The theories we examined focus on the effects of increasing proportional representation of women; they are silent about the effects of stalled or decreasing women's representation. We encourage future work that builds and tests theories about the relationship between gender, the structure of collaboration networks, and citations during periods when the rise in the proportion of women stalled or even declined.

We treated the effective size of isolates—individuals who published one or more sole authored papers during a time window—as undefined. Alternative models that assigned a zero for effective size for isolates and used its log-transformed form yielded a similar pattern of results. Isolates have received relatively little attention in network theory because the minimal unit of network analysis is the dyad (Chen et al., 2022). One could argue, therefore, that network theory is not relevant to an understanding of isolates. Nonetheless, scholars interested in gender differences in citations may find it useful to theorize about the causes and consequences of being an isolate in the collaboration network.

Our study was restricted to a single academic field: management. This mono-disciplinary focus means that we did not have to adjust for the many field-level differences that shape how new knowledge is produced and consumed, such as the size and maturity of a field, and differences in norms about who is and who is not included on research papers (Moody, 2004). The obvious downside of our focus on a single academic field is that it raises questions about the generalizability of our results to other academic fields. We encourage researchers to examine how legitimacy has shaped returns to brokerage for women and men in other fields and also in organizational settings where similar knowledge work is done. Any future replication will, as in our study, require data on the effects of structural holes as the proportional representation of women in the setting changes over time.

The focus of our investigation is gender. This is an important demographic characteristic given its societal importance, and women's historical disadvantage in the realm of science. However, there are other demographic characteristics, such as ethnicity and country of national origin, that are also of societal importance and may be associated with outsider status in science in much the same way as gender has historically been. Moreover, these other characteristics may intersect with gender (Crenshaw, 1989) to mitigate or strengthen the effects of gender and collaboration networks on the accrual of citations. For example, the kinds of networks associated with citations for white women may be different than those associated with citations for Asian women. This is a topic for future research. We have treated gender as binary, but gender is in fact multifactorial and complex (Spence & Buckner, 2000). Even if one cannot be more or less female, one can be more or less feminine (Bem, 1974). Studying the effects of such distinctions on how people build and benefit from collaboration networks will probably require self-reported data on gender and gender identity.

Conclusion

We live in such information-rich worlds that one could argue it is attention not knowledge that is the scarcer resource. To have others cite the knowledge one produces, a collaboration network with the right structure can be an advantage. What our study emphasizes is that the right network structure can be different for women and men, and this difference is itself contingent on the changing proportions of women in the field. There is compelling evidence of gender-based inequalities across a range of industries and institutions, including those dedicated to the production and dissemination of academic business knowledge (Joshi, Son, and Roh, 2015; Fox, 2006). Building the right collaboration networks can help women combat bias (e.g., Greguletz, Diehl, & Kreutzer, 2019; Snellman & Solal, 2023), but – consistent with Blalock's intrusiveness theory – our study suggests that the kind of network that is advantageous for women changes as their proportion in the field changes. In using an abductive approach to sort through competing yet plausible theories of the role social network structure and proportional representation play in helping women scholars get their new ideas noticed and used by others, we hope to contribute to the vital debate regarding women's academic careers and the advancement of the fields they work in.

Table 1. Means, standard deviations, and correlations among study variables.*

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12
1. Number of new papers	2.07	1.65												
2. Years since PhD	8.52	7.06	-.01											
3. Prior citations	29.53	66.96	.39*	.32*										
4. Current institution's citations	350.27	428.60	.24*	.13*	.36*									
5. Graduate institution's citations	778.31	704.31	.15*	.07*	.24*	.42*								
6. First authorship	1.01	1.96	.37*	.36*	.82*	.29*	.15*							
7. Last authorship	.84	1.69	.33*	.38*	.78*	.28*	.15*	.79*						
8. Co-author citations	30.77	94.69	.31*	.09*	.53*	.24*	.23*	.39*	.34*					
9. Isolate	.68	.47	-.32*	-.18*	-.46*	-.20*	-.15*	-.46*	-.42*	-.44*				
10. Gender (1=female, 0=male)	.22	.41	-.06*	-.14*	-.04*	.06*	.12*	-.08*	-.09*	.03*	.05*			
11. Structural holes	.94	.37	.32*	.17*	.56*	.25*	.11*	.49*	.45*	.44*	.	-.02		
12. Proportion of women PhDs	.26	.07	.08*	.16*	.18*	.32*	.47*	.12*	.11*	.18*	-.14*	.15*	.10*	
13. Number of citations	36.19	47.14	.74*	.01	.37*	.28*	.14*	.31*	.28*	.25*	-.25*	.01	.25*	.13*

* *n (number of authors)* = 3888. * $p < .05$.

Table 2. Random effects negative binomial regression predicting number of citations.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
<u>Control variables</u>						
Number of new papers [a]	.30***	.30 ***	.27***	.27***	.26***	.26***
	(.00)	(.00)	(.01)	(.01)	(.01)	(.01)
Years since PhD [a,b]	-.02***	-.01 ***	-.01***	-.01**	-.01**	-.01**
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)
Prior citations[a]	-.00***	-.00***	-.00***	-.00***	-.00***	-.00***
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)
Current institution’s citations [a,b]	.00***	.00***	.00***	.00***	.00***	.00***
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)
Graduate institution’s citations [a]	-.00**	-.00**	-.00**	-.00*	-.00**	-.00**
	(.00)	(.00)	(.01)	(.00)	(.00)	(.01)
First authorship	.03***	.03***	.02*	.02*	.02*	.02*
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
Last authorship	.06***	.06***	.04***	.04***	.04***	.04***
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
Co-author citations[a]	.00**	.00**	.00**	.00**	.00**	.00**
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)
Isolate (1 if isolate)	.04*	.03				
	(.02)	(.02)				
<u>Independent variables</u>						
Gender (1 if woman)		.12***	.11*	.09†	.11*	.16**
		(.02)	(.05)	(.05)	(.05)	(.06)
Structural holes[a]			.01	.04	.01	.05
			(.04)	(.04)	(.04)	(.04)
Proportion of women PhDs[a]					1.90**	2.07**
					(.62)	(.62)
<u>Interaction terms</u>						
Gender x structural holes				-.24**		.09
				(.08)		(.12)
Gender x proportion of women PhDs						-1.06
						(.78)
Proportion of women PhDs x structural holes						-.56
						(.51)
Gender x proportion of women PhDs x structural holes						-5.69**
						(1.81)
Wald Chi-square	7,291.60***	7,307.52***	3,034.93***	3,042.39***	3,043.65***	3,062.07***
Log likelihood	-29,226.52	-29,215.18	-10,127.90	-10,123.10	-10,123.17	-10,111.59
Number of author-year observations	7,103	7,103	2,286	2,286	2,286	2,286
Number of authors	3,888	3,888	1,012	1,012	1,012	1,012

Note. Standard errors are in parentheses. All models have been estimated with dummy variables for 5-year periods. *** $p < .001$ ** $p < .01$ * $p < .05$ † $p < .10$.
[a] These variables have been centered. [b] These variables have been calculated with mean replacement.

Table 3. Flood light analysis showing significance of parameter estimate representing effects of structural holes on citations to women at different levels of proportional representation in the field.

Proportion of Women Receiving PhDs	Structural Holes (Effective Size)	p value
5.0	0.422	0.005
7.5	0.378	0.005
10.0	0.333	0.006
12.5	0.288	0.008
15.0	0.243	0.010
17.5	0.199	0.015
20.0	0.154	0.024
22.5	0.109	0.049
25.0	0.065	0.135
27.5	0.020	0.539
30.0	-0.025	0.314
32.5	-0.070	0.003
35.0	-0.114	0.000
37.5	-0.159	0.000
40.0	-0.204	0.000

Figure 1. The interactive effects of gender and structural holes on citations.

Note. Structural holes were measured using the log transformation of Burt's (1992) measure of Effective Size.

Figure 2A. Interactive effects of structural holes and proportion of women PhDs on citations to men.

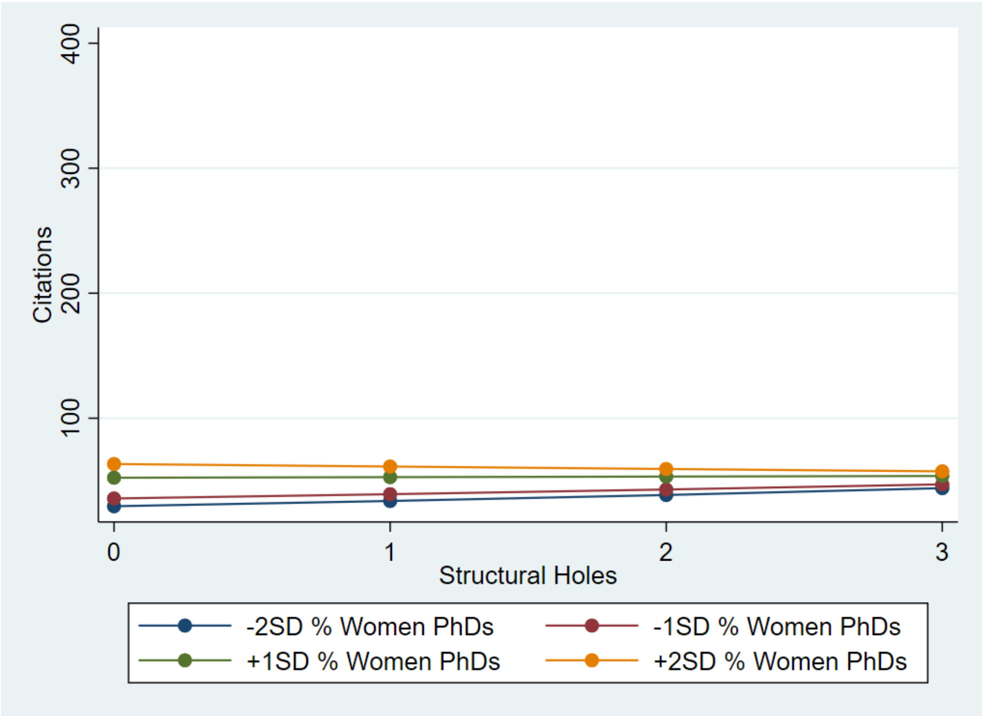
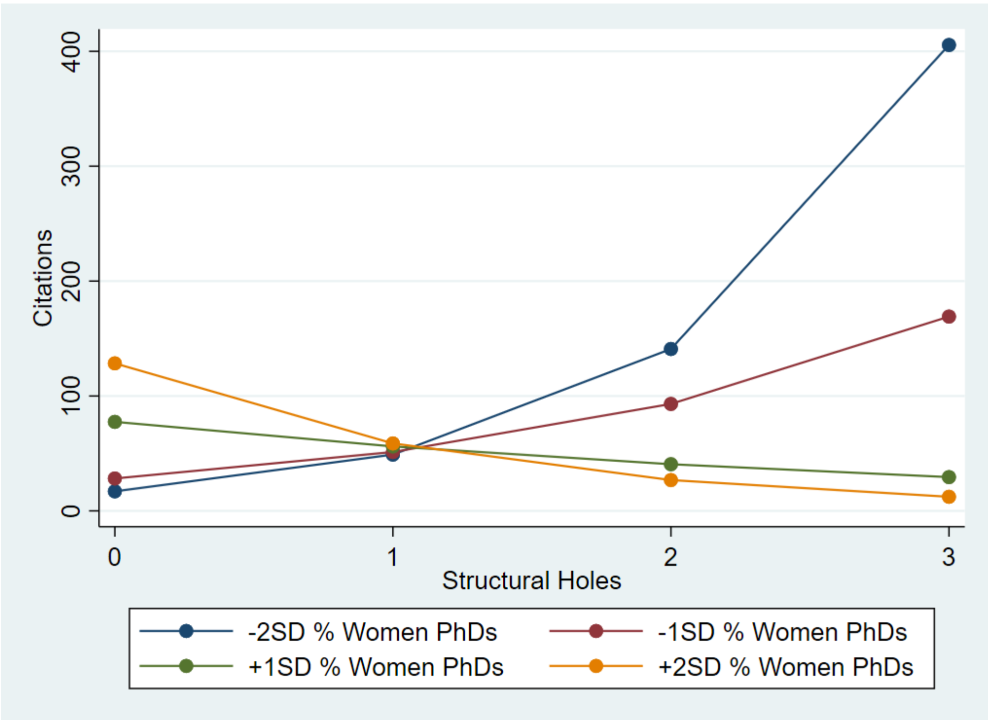


Figure 2B. Interactive effects of structural holes and proportion of women PhDs on citations to women.



Note. Structural holes were measured using the log transformation of Burt's (1992) measure of Effective Size.

Appendix. A summary of key study variables, measurement, and data sources.

Variables	Measurement	Data Sources
Dependent Variable		
Citations	A count of citations received within five years of a paper's publication ("five-year citations"). Citations were counted irrespective of the journal in which the citation occurred.	Web of Science, EBSCOHost
Independent Variables		
Gender	Coded as a dichotomous variable (1 = women, 0 = men) based on a three-step process: 1) PHP program querying "Behind the Name" for gender, 2) author biographies for missing gender, and 3) online searches for further verification.	"Behind the Name" (http://www.behindthename.com), Biographies, Online Webpages and Profiles
Structural Holes	In network theory, "structural holes" reflect holes in social structure—i.e., they represent the absence of direct connections between parties connected to the same focal individual (Burt, 1992). Individuals who have large, sparsely connected personal networks have networks rich in structural holes. We measured structural holes in an individual's collaboration network from t-5 to t-1 using Burt's (1992) measure of "effective size." Applied to the collaboration network, effective size was the number of co-authors minus the average number of ties among co-authors. To address skewness, we used the log-transformed version of effective size, calculated as (log (effective size+1)).	Co-authorship Data from Web of Science and EBSCOHost. Restricted to publications in five "elite" management journals: Administrative Science Quarterly, Academy of Management Journal, Academy of Management Review, Organization Science, and Strategic Management Journal.
Proportion of Women PhDs	Percentage of PhD degrees in business granted to women in a focal year.	AACSB
Control Variables		
Years Since PhD	A count of the years since an author received the PhD.	ProQuest, Online Profiles
Prior Citations	A count in year t of the number of citations to an author's publications in the previous five years (i.e., from t-5 to t-1), irrespective of the journal where the citation occurred.	Web of Science, EBSCOHost
First Authorship	The number of papers an author published as first author during the period t-5 to t-1.	Web of Science, EBSCOHost. Restricted to publications in five elite management journals.
Last Authorship	The number of papers an author published as last author during the period from t-5 to t-1.	Web of Science, EBSCOHost. Restricted to publications in five elite management journals.
Current Institution's Citations	The cumulative number of "five-year citations" to publications for authors affiliated with the university from 1970 to t-1.	Web of Science, EBSCOHost
Graduate Institution's Citations	The cumulative number of "five-year citations" to publications by an author's graduate institution from 1970 to t-1.	Web of Science, EBSCOHost, ProQuest, Online Profiles
Co-author Citations	The number of "five-year citations" to the papers published by an author's co-author(s) from t-5 to t-1.	Web of Science, EBSCOHost
Isolates	Coded as 1 if the person published only sole-authored articles in the five elite journals during the period t-5 to t-1; and 0 otherwise.	Web of Science, EBSCOHost

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