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"A tie is a tie? Gender and network positioning in life science inventor collaboration"

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ABSTRACT

Collaborative relationships are an important anchor of innovative activity, and rates of collaboration in science are on the rise. This research addresses differences in men's and women's collaborative positioning and collaborator characteristics in science, and whether network influences on scientists' future productivity may be contingent on gender. Utilizing co-inventor network relations that span thirty years of global life science patenting across sectors, geographic locations, and technological background, I present trends of men's and women's involvement in patenting and their collaborative characteristics across time. Amidst some network similarities, women are less likely to connect otherwise unconnected inventors (brokerage) and have greater status-asymmetries between themselves and their co-inventors. In multivariate models that include past and future activity, I find that some network benefits are contingent on gender. Men receive greater returns from network positioning for brokerage ties, and when collaborating with men. Women benefit from collaborating with women, and are more likely to collaborate with women, but both men and women collaborate with mostly men. I discuss the implications of these results for innovative growth, as well as for policies that support men's and women's career development.

1. Introduction

Amidst extraordinary strides over past decades, there remain persistent inequities between women and men in a host of outcomes regarding activity in science, technology, engineering, and mathematics (STEM) fields. These include disparities in scientific degree attainment, science labor force participation, salary, the distribution of positions and achievements, material resources and rewards (Long, 2001; Xie and Shauman, 2003; Rosser, 2010). Scholarly and public discussion has highlighted important influences on women's career attainment stemming from the culture and practice of science, the organization and the arrangement of scientific work, and the influence of intersecting social institutions such as marriage and family (National Academy of Sciences, 2006).

Despite focused attention on the topic, less is known about women's collaborative activity, compared to men, specifically regarding their network positioning in research networks and across the science research context (Meng and Shapira, 2010; Meng, 2013; Sugimoto et al., 2015). Scientific collaborations are the backbone of a successful career in science. Research ties facilitate links to additional contacts, assist the diffusion of emergent knowledge streams, and can provide scientists with access to new research opportunities across institutional, disciplinary, and geographic boundaries (Singh and Fleming, 2009; Inoue and Lui, 2015). Collaboration is also increasingly requisite; rates of collaborative efforts in science are increasing as "lone authorships" are in decline (National Science Board, 2004; Greene, 2007). Amidst an expanding scale of research (as well as significant fiscal constraint), funding institutions are now investing more and more in team science and interdisciplinary initiatives (Bennett et al., 2010; Adams 2012).

A lack of understanding of where women scientists "sit" in networks of collaboration means that little is known about women's embeddedness in the social structure of science, compared to men, as well as how this embeddedness has (or has not) changed over time. Science collaboration is built upon sets of repeated and reciprocal relations between scientists, and linkages between collaborators (and the collaborators of their collaborators) knit together a network of relations (Fleming and Marx, 2006). A scientist's location in this network and the relationships they form and sustain are shaped by the overarching status structure of science, in which hierarchical gender relations prevail (Fox et al., 2017). Against this backdrop is speculation that network benefits may be contingent on gender. By examining gender differences in collaborative positioning, and whether and how network benefits are contingent on gender, it is possible to identify critical factors related to network positioning and women's career attainments in science, and to inform theoretical perspectives about collaborative network mechanisms more generally.

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Using the case of patenting collaboration networks in the life sciences, I construct a global patenting collaboration network of ~216 K men and women inventors on ~784 K life science patents across a period of three decades (1976–2005). The collaborative relationships are time-ordered and dynamic, and any given network year represents a portrait of inventors working (individually or together) on commercial research endeavors. Their collaborative relationships define a network of linkages that cross geographic and institutional boundaries through much of the rise and early institutionalization of the biotechnology industry.

The novelty of this data, and the information it provides, comes from the incorporation of two increasingly prevalent, yet not previously combined, strategies to ascertain information about scientific collaboration in a network context. The first regards the challenge of disambiguating patenting and publishing records. Until very recently, data was not readily available to link inventors and authors to their patenting and publishing records in a way that would allow researchers to easily construct unique collaborative profiles for scientists over time. Although not hindering research completely (see, for example, Fleming and Marx, 2006; Lai et al., 2010; Lai et al., 2011; Inoue and Liu, 2015), this has slowed the proliferation of knowledge about collaborative networking in science. In this research, I follow efforts of previous work to disambiguate inventor records and construct networks of collaboration over time (Lai et al., 2010; Lai et al., 2011). Similar efforts can be found in the United States Patent and Trademark Office (USPTO) PatentsView platform, which employs probabilistic methodologies to disambiguate inventor records in a relational database (USPTO, 2016).

The second challenge relates to the omission of gender identity[1] in patenting and publishing records (Frietsch et al., 2009). While information on women's patenting and publishing activities can be gathered by self-report on surveys, or through hand-coded case studies, the lack of information at the record level complicates research on men's and women's network positioning, because details about science collaborators (and the collaborators of their collaborators, etc.) need also be known. In this work, I utilize name frequency databases to create a probabilistic likelihood of inventors being male or female, a strategy in line with others (Moody, 2004; Frietsch et al., 2009; Meng, 2013; Sugimoto et al., 2015; Larivière et al., 2013). Although an imperfect method, such data would be challenging to procure otherwise; indeed, organizations with substantial resources otherwise have, and continue to, rely on similar methodology (Elsevier, 2016, 2017).

To this researcher's knowledge, this work represents the first effort to employ both strategies in a relational fashion to address questions about women's collaborative positioning, compared to men, using network methodology in a global network context over time.[2] I use this network to present descriptive statistics on inventors patenting rates and collaborative profiles, over time, as well as to report on a wide variety of network measures commonly considered to be relevant to innovative output. I then leverage the longitudinal nature of the data, and its relational components, to investigate the possible moderating influence of gender on network benefits to scientists' future commercial activity, finding evidence of some network contingencies for men and women inventors.

2. The case: patenting in the life sciences

My focus on patenting – as opposed to other collaborative endeavors in science – is guided by both methodological and substantive factors. While publishing has long been regarded as the "coin of the realm" for academic science (Storer, 1973), this sector has witnessed a sea change in recent decades with an explosive increase in patenting, licensing, start-up incubation, and founding of companies, most notably in the life sciences (Henderson et al., 1998; Mowery et al., 2001; Owen-Smith, 2003; Owen-Smith and Powell, 2003). At the same time, scholars have recently turned an analytical lens beyond publication to additional indicators of research productivity, including those related to academic and industrial entrepreneurship and commercial activity. Innovation is connected to increased publication productivity (Stephan et al., 2007; Azoulay et al., 2009), and is valuable for academic success and rewards more broadly (Jacobs and Frickel, 2009). In addition, a focus on patenting allows for attention to be paid to the relationship of institutional location and gender equity in science, as the commercial context involves activity beyond academia in industry science, non-profit research institutes, government agencies, and pharmaceutical firms and chemical companies. Cross-sector activity knits together the social structure of science and presents a more accurate portrayal of science collaborations in the biomedical sciences. Methodologically, patenting data is publicly available, and is widely used in social and economic circles to assess individual, state, regional, and national indicators of innovative activity. A base of knowledge exists about inventor network relationships in the science realm (Fleming et al., 2007; Balconi et al., 2004; Obstfeld, 2005; Inoue and Liu, 2015), allowing for useful comparisons and meaningful implications.

While patenting and publishing activities are distinct – patents grant exclusive rights, and must meet criteria of being useful, novel, and non-obvious – there are similarities. Both tend to be conducted by teams of scientists utilizing recognized research practices, who formulate claims based on extant literature. Both codify results and mobilize evidence, and are governed by an external evaluation system. Furthermore, scientists with academic ties often publish and patent the results of the same research activities in patent/publication pairs (Murray, 2002; Murray and Stern, 2007). That said, commercial activity is more likely to be taken on by those who are highly productive in other performance metrics, such as publishing (Stuart and Ding, 2006), and to occur in certain settings over others (such as industrial science, and in research universities). The concern regarding women's involvement is that the increased emphasis on commercial activity may heighten gender gaps in status because those who are already successful appear better able to capitalize on commercial success (Colyvas et al., 2012).

As with publishing, a considerable body of research has found that women receive fewer patents than men, and patent at lower rates, with some decrease in the gender disparity over time (Naldi et al., 2005; Thursby and Thursby, 2005; Ding et al., 2006; Stephan and El-Ganainy, 2007; Kugele, 2010; Colyvas et al., 2012; Sugimoto et al., 2015). Some industry settings – particularly firms of a "network form" (Powell, 1990)—reveal more equity than others (Whittington and Smith-Doerr, 2005, 2008). Compared to men, women are also less likely to be present in other commercial endeavors, such as licensing (Duque et al., 2005), consulting (Corley and Gaughan, 2010), participation in private sector scientific advisory boards (Ding et al., 2013), and company founding (Lowe and Gonzalez Brambilia, 2007). Research finds that a significant hurdle for women may occur at the stage of *first* involvement, especially in the academy where such activities are not "required" (Whittington, 2011). In interviews with women scientists at a prominent university, Murray and Graham (2007) report that women describe less exposure to the commercial process and fewer opportunities to disclose than men (see also Ding et al., 2006). Women also report fewer invitations from others to participate in commercial activity, and different sources of support for commercial involvement then men—women from close colleagues in comparable positions (and from technology licensing offices), and men from senior advisors.

Women patent less than men, however it remains unknown how they are integrated in the broader collaborative community. Given the importance of network factors in innovative activity more generally, it

[1] The terms "sex" and "gender" commonly refer to the biological versus social construction of men and women. In this analysis, I use "gender" to refer to both physical and social difference, and use the terms "men and women" and "male and female" interchangeably.

[2] See Frietsch et al. (2009) and Meng (2013) for comparable work outside of a network context. Outside of gender, see work by Fleming and colleagues (Fleming and Marx, 2006; Fleming et al., 2007) and Inoue and Liu (2015).