From Bench to Board: Gender Differences in University Scientists' Participation in Corporate Scientific Advisory Boards

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ABSTRACT

This paper examines the gender gap in the likelihood that academic scientists join corporate scientific advisory boards (SABs). We assess (i) demand-side theories that relate the gap in scientists' rate of joining SABs to the opportunity structure of SAB invitations, and (ii) supply-side explanations that attribute the gap to scientists' preferences for work of this type. We statistically examine the demand- and supply-side perspectives in a national sample of 6,000 life scientists whose careers span more than 30 years. Holding constant professional achievement, network ties, employer characteristics and research foci, male scientists are almost twice as likely as females to serve on the SABs of biotechnology companies. We do not find evidence in our data supporting a choice-based explanation for the gender gap. Instead, demand-side theoretical perspectives focusing on gender-stereotyped perceptions and the unequal opportunities embedded in social networks appear to explain some of the gender gap.

INTRODUCTION

The gap in labor market outcomes between men and women has been gradually decreasing for decades, but the underrepresentation of women in high-level corporate positions stubbornly persists. Among Fortune 500 companies, for example, women currently hold only 16% of all board seats and 14% of all executive–level positions (Catalyst, 2011).

Scholars seeking to explain this gap generally have approached the issue from one of two, distinct theoretical approaches. Demand-side perspectives developed in sociology and social psychology focus on the mechanisms that limit opportunities for women to gain access to jobs of certain types. By contrast, supply-side perspectives developed in economics emphasize that individual differences in preferences lead to worker-level choices that drive labor market outcomes. According to this view, skill and preference differences between the genders—rather than systematic biases in the workplace—explain gender-based differences in career outcomes.

Vibrant research streams underlie both perspectives. Findings from them, however, imply quite different remedies to the persistent gender gap. Moreover, to the best of our knowledge, there are no longitudinal studies that empirically compare, side-by-side, the relative importance of the two broad families of theories. Most archival, demand-side studies that have investigated discrimination in the evaluation of women for top positions (e.g., Gorman, 2005; Gorman & Kmec, 2009; Westphal & Stern, 2006) implicitly assume that all eligible candidates are motivated to pursue the positions of interest. Conversely, supply-side studies often regress career outcomes (e.g., compensation) on a collection of explanatory variables that are believed to proxy for human capital and worker preferences. In such studies, the residual, unexplained variance in pay or promotion then may be attributed to discrimination (e.g., Bertrand & Hallock, 2001; Goldin & Katz, 2008).

We believe that an integrated empirical test incorporating both supply- and demand-side perspectives is of considerable value. On one hand, assuming away supply-side explanations undercuts the validity of research that has found systematic discrimination in the opportunity structure for women to ascend to the top of the corporation. In this sense, studies that account for supply-side explanatory factors are necessary for accurate estimates of the extent of gender-based discrimination. Of course, the same logic applies conversely; the persuasiveness of evidence for supply-side theories is diminished in the absence of accounting for workplace biases. Therefore, integrative investigations are necessary to begin to adjudicate between the two families of explanations and to better pinpoint the factors that contribute most to the gender gap in senior-level corporate roles.

Undoubtedly, a primary explanation for the paucity of research that jointly considers both the supply and demand sides of the equation is the challenge of collecting appropriate data. In many empirical settings, it can be difficult even to define the pool of candidates for open positions. In situations when the candidate pool can be approximately bounded (e.g., Gorman & collaborators [2005, 2009] for partnerships at law firms; Westphal & Stern [2006] for board positions at Fortune-500 firms), researchers still face the daunting task of collecting detailed career histories for members of the pool.

The empirical approach in this paper overcomes some of these limitations. First, we study the gender gap in participation in scientific advisory boards (SABs) in the biotechnology industry. The importance of greater female representation on these boards is certainly one reason for this choice. Another attractive feature of SABs is that the process of appointing individuals to them largely resembles that for a corporate board of directors—in both contexts, new members join by invitation (i.e., one typically does not volunteer for such roles), and a variety of social mechanisms are invoked in the vetting process (Khurana, 2002). More importantly, SAB members in the context we study, the life sciences industry, largely are chosen from the pool of university professors in relevant fields of science. This allows us to identify the candidate pool and to construct a dataset of eligible recruits. Likewise, because our study population consists of academic scientists, there is a wealth of publicly available information about their career histories and professional achievements, and with a little creative license, we also can construct indicators of the extent to which a given academic scientist has expressed interest in working with private sector companies. Together, the career histories and the proxies for interest in opportunities in SAB positions enable us to simultaneously assess demand- and supply-side perspectives.

Theoretically, we build most heavily from four streams of existing literature to develop our hypotheses about gender differences in participation in SABs: (i) expectation-state theory that considers when gender is used by an evaluator to infer a candidate's competence (Berger, Rosenholtz & Zelditch, 1972; Ridgeway & Erickson, 2000); (ii) role-congruity theory (Eagly, Karau, & Makhijani, 1995; Eagly & Karau, 2002; Eagly, Makhijani, & Klonsky, 1992) and lack-of-fit theory (Heilman, 1983, 2001), which argue that the disadvantages women face in the workforce arise from an incongruity between the qualifications for a position and characteristics that a female candidate is conventionally expected to possess; (iii) social network theory, which often finds gender-based differences in network structures, with implications for access to the professional opportunities that are allocated across networks; and (iv) a supply-side perspective that attributes the gender gap to individual career choices and preferences and maintains that the resulting accumulation of human capital determines career outcomes (Becker, 1985; Bertrand, Goldin, & Katz, 2010).

Before developing hypotheses, we first present a brief overview of the role of SABs. After this description, we formulate predictions regarding gender differences in the likelihood of joining SABs. These hypotheses are then tested in a case-cohort data archive containing career histories of a national sample of 6,000 university-employed life scientists.

SCIENTIFIC ADVISORY BOARDS (SABS)

Functions of SAB

Despite all the interest in commercial endeavors in academic settings, SABs have received little attention in the literature to date and, in consequence, their function is not well understood. Based on our interviews of scientists who have been SAB members, SABs have neither fiduciary responsibility nor a formal place in a firm's governance structure.[1] Nevertheless, they have become a near-ubiquitous feature of biotechnology companies. Typically SABs are formed by the founding team very early in the development of the firm and consist of five to ten members who join by invitation. The founding scientist(s) of a biotechnology company and their investors identify suitable SAB candidates through their contact networks or based on their knowledge of the experts in the company's field of research. Once formed, SABs remain quite stable and replacement of members is uncommon. Board meetings typically occur quarterly, during which SAB members review the firm's key research projects. SAB members are typically paid a fee and granted stock options that can run as high as 2% of a startup company's equity.

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[1] As part of a broader research program that examines the underpinnings of the transition to commercial science among academic scientists, we conducted extensive interviews with a gender-matched sample of life scientists at one of the universities that has been most active in the commercialization of academic science. For further details, please see Ding, Murray, and Stuart (2010).

The scientists we interviewed believe that SABs perform three primary functions. First, they provide expertise, ranging from very specific tacit knowledge to general advice on broad scientific strategies and experimental designs. In addition to offering their expertise, a second function of the SAB is to signal scientific quality to external investors. Our interviewees often likened advisory boards to "*window dressing*". In effect, prestigious academic scientists lend their reputations to the early stage firms they advise, which aids firms in attracting financial resources and recruiting scientific talent. A third obligation is that SAB members are expected to share their social networks with the firm: they assist in identifying other academics that might provide a critical resource through collaborative research, and they locate suitable students to be hired by the firm.

Why Study SABs?

Research design considerations aside, our decision to study SABs is motivated by the substantive importance of these advisory boards. First, we note that among the small number of studies that have investigated SABs (Audretsch & Stephan, 1996; Ding & Choi, 2011; Louis, Blumenthal, Gluck, & Stoto, 1989; Stuart & Ding, 2006), none have addressed the gender gap in participation rates.

Second, Whittington and Smith-Doerr (2005) have argued that female involvement in commercial science may be aptly characterized by a gender-based "pipeline" analogy (Berryman, 1983). As the degree of commercial involvement increases and the level of time and identity commitment intensifies—for instance, as one moves across a continuum from consulting to patenting to SAB member to founding a company—one would expect a decreasing number of women scientists. Given that the time commitment and financial and reputational rewards for SAB involvement is more substantial than for episodic commercial activities such as patenting and consulting, in the pipeline analogy, SAB membership is nearer to the pinnacle of commercial engagement than other widely studied practices, most notably patenting.

Third, we believe that the gender composition of SABs has implications for female representation in biopharmaceutical firms and possibly for the career outcomes of women employees in these firms. To the extent that in-group favoritism and social network ties influence recruiting, having more women in key corporate positions such as board, advisory board and senior executive ranks should create opportunities for other women to ascend to senior-level positions (Beckman & Phillips, 2005; Cohen, Broschak, & Haveman, 1998; Gorman, 2005; Gorman & Kmec, 2009). In addition, research on gender effects in supervisory and mentoring relationships (Tsui & O'Reilly, 1989) suggests that the presence of women at the top of an organization has a positive, trickle-down effect on the career experiences of female employees.

Fourth, SAB membership has important implications for the gender gap in compensation in academia. A recent survey of newly public biotechnology companies (IPO class of 2004) found that in half of the firms, university faculty had large enough equity holdings to be listed in Securities and Exchange Commission filings, with a median value of $5.6 million (Edwards, Murray, & Yu, 2006). Apart from direct financial returns, SAB membership also bolsters scientists' reputation in industry, which may translate into lucrative consulting work. Therefore, opportunities for extramural work such as SABs now meaningfully influence earnings differences among scientists, and any gender differences in participation on SABs may become a growing source of earnings inequality in the profession.

HYPOTHESES

Building on the literature on gender and careers, we formulate hypotheses that specify demand-side and supply-side explanations for gender differences in faculty participation in SABs.

Overall Gender Gap

Our first objective is to determine whether there is a gender gap in the participation of university scientists in for-profit companies' SABs, and if so, to gauge its magnitude. There is ample reason to anticipate that such a gap may exist. First, a long tradition of research examines the effect of gender on different aspects of scientific careers. With few exceptions, this work has concluded that female scientists who are otherwise comparable to their male colleagues experience less successful careers by the standard metrics of professional attainment (Fox, 2001; Haberfeld & Shenhav, 1990; Long & Fox, 1995). Specifically, women scientists are less productive than men (Cole & Zuckerman, 1984; Reskin, 1978; Long, 1990; Xie & Shauman, 1998) they are less likely to be on the faculties of elite institutions (Long & Fox, 1995); they advance ranks at a slower rate than men (Farber, 1977; Long, Allison, & McGinnis, 1993; NSF, 2005); and a salary gap continues to exist (Haberfeld & Shenhav, 1990; NSF, 2005).

There is some evidence suggesting a gender gap in commercial science as well. Ding, Murray and Stuart (2006) found that over a 30-year period, men patent at about 2.5 times the rate of women. Whittington and Smith-Doerr's (2005) reached a similar conclusion in studies of NIH grant awardees. In a study of 4,500 faculty members, Thursby and Thursby (2005) showed that women are less likely than men to disclose potentially patentable inventions to university technology transfer offices. Corley and Gaughan (2005) found that women faculty engage in less consulting than men. Finally, Rosa and Dawson (2006) found that only 12% of the founders of all companies spun out of U.K. universities were female.

Because SABs typically are created early in the life of a new company, the broader evidence concerning gender differences in other forms of entrepreneurship in society at large may be informative in this context. For instance, there is known to be a wide gender gap in company founding rates. Statistics indicate that men start new businesses at approximately twice the rate that women do (US SBA, 2001). Moreover, the disparity between the genders in rates of business founding and in occupancy of high-level managerial positions appears to increase with the technological intensity of the sector (Baron, Hannan, Hsu, & Kocak, 2001). For example, a study of venture capital funding activity in 2000 found that just six percent of the $69 billion funds dispensed by the industry was invested in companies with a female chief executive officer (Brush, Carter, Gatewood, Green, & Hart, 2001).

Given the sizable gender gap in academic career outcomes, the documented gap in other forms of commercial science, and the under-representation of women in technology-sector entrepreneurship, we posit as a baseline expectation: women academic scientists are less likely than men to join the scientific advisory boards (SABs) of biotechnology firms.

Hypotheses from the Demand-Side Perspective

Assuming a gender gap in SAB membership, what are the factors that might contour it? The literature focuses on two broad classes of mechanisms underlying gender differences in career outcomes: demand-side biases in the workplace that cause women of equal qualifications to male colleagues to obtain fewer opportunities to join advisory boards, and supply-side explanations that emphasize the exercise of individual choices that shrink the pipeline or diminish the interest of eligible women candidates with the right qualifications for positions of this type. In demand-side perspectives, the dominant logic is one of blocked mobility because of prevalent workplace biases. Conversely, supply-side arguments are based on differences in individuals' choices to invest in human capital or to supply labor.

We begin with demand-side perspectives. In considering these theories, we follow the general approach in Petersen and Saporta (2004), who assume that gender-based discrimination is widespread in organizations and then investigate the circumstances under which the prevalence of discrimination is expected to vary. Similar to Petersen and Saporta (2004), we do not directly observe discrimination. Rather, our research strategy asks, *if* discrimination is commonplace, what does this imply in terms of contextual factors that theory predicts will moderate its effect? We derive hypotheses based on the implications of the demand-side theories that suggest amplifiers or dampeners of the base-case level of the observed gender gap.

We focus on three groups of theory of how gender may influence an evaluator's assessment of an applicant's qualifications for a job: (i) expectation-states theory, (ii) role-congruity and lack-of-fit theories, and (iii) in-group favoritism and social networks. No doubt, these are just a subset of the theoretical possibilities that could explain the gender gap. For instance, we do not address demographic perspectives (cf. Beckman & Phillips, 2005; Cohen, Broschak, & Haveman; 1998), job matching theory (Reskin & Roos, 1990), or theories of the impact of specific organizational practices (cf. Dencker, 2008; Roth, 2006). In formulating our argument, our theoretical lenses were focused by the relevance of theories to our research context and by what we can measure in our empirical data.

Expectation states theory. Expectation states theory describes how status beliefs are constructed during the process of social interaction. Ridgeway (2001) defined status beliefs as "widely held cultural beliefs that link greater social significance and general competence, as well as specific positive and negative skills, with one category of a social distinction (e.g., men) compared to another (e.g., women)". Research has found that in many contexts, gender is a prominent social category that is associated with anticipated performance levels even when there is no actual relationship between gender and relevant outcomes (e.g., Berger, Cohen, & Zelditch, 1972; Ridgeway & Erickson, 2000). In other words, an individual's gender may elicit presumptions about his or her ability to perform a particular task or role—and therefore influence whether that person is presented with opportunities to execute the task in the first instance—in contexts in which there are gender-based assumptions about ability. This process is documented to occur in many situations in which gender is unrelated to ability.

In the context of SABs, we know from the general function of advisory boards that there is a premium placed on selecting advisors who are perceived to be of high status within the scientific community. Moreover, we know that success in the resource mobilization process for new ventures hinges on the legitimacy and the status of the entrepreneurs attempting to attract resources (e.g., Shane & Stuart, 2002; Stuart, Hoang, and Hybels, 1999). Even when a woman occupies the same formal position as a man (e.g., professor at the same university), the fact that women are atypical occupants of such positions may lead SAB selectors to form gendered status beliefs which hold that women are less competent than men at performing the tasks of a SAB member (Kanter, 1977; Ibarra, 1992; Lucas, 2003; Ridgeway & Smith-Lovin, 1999).

Expectation states theory contrasts with supply-side explanations of gender differences in opportunity structures of the type we study in that it posits that actors often hold different, gender-based *perceptions* of candidates' competence, versus supply-side perspectives that attribute the difference to candidates' competence per se. While supply-side perspectives attribute the gap to women's lack of interest or qualifications for SAB positions, expectations states theory points us to the differences in SAB selectors' *subjective* interpretation of candidates' qualifications based on gender (or other) categorical differences.

Assuming that subjective frameworks rooted in perceptions of gender differences affect evaluations of potential SAB members, expectation states theory implies two possible outcomes. First, there may be a gap between a candidate's true qualifications and an evaluator's perception of them, and this gap varies between genders. To the extent that being female connotes a presumption of inferior status, women scientists are likely to be disadvantaged in the SAB vetting process even when they hold the same qualifications as their male counterparts. Second, if subjective evaluative frameworks play a strong role in SAB selection, then the theory implies that the degree of gender bias is likely to vary with how and which subjective frameworks are invoked in the evaluation process. When multiple frameworks jointly influence the process, the degree of negative perceptions of a woman's competence can be mitigated (or aggravated) depending on whether there are competing frameworks that weaken (or strengthen) the impact of gender-disadvantageous status beliefs. Lacking direct information on SAB selectors' perceptions, we focus our hypothesis on the second of these two possibilities.

Social psychologists have shed light on how multiple status categories operate together. Research shows that although it is often salient, gender is one of many ways in which individuals are categorized. As information on additional social categories becomes available, it cognitively nests within gender categories and it may alter the interpretation of gender identities (Stangor, Lynch, Duan, & Glass, 1992). Ridgeway and Correll (2000) observe that other identities, particularly those based on institutional roles (e.g., CEO, university professor), may operate in the *foreground* while gender operates as a *background* factor in evaluative settings. Their research suggests that, in certain situations, the invocation of other social categories as bases of evaluation may modify gender-based assumptions of competence.

Among the kinds of information likely to be invoked in the vetting process for prominent corporate positions, employment affiliations loom large. For example, Crane (1965) famously found that scientists gain greater recognition from an affiliation with a prestigious university than they do even from their own, high productivity. In the context of selection of board members for early stage technology companies, the prestige of a scientist's employing university itself lends legitimacy to the venture (Sine, Shane, & Di Gregorio, 2003; Stuart et al., 1999). To the extent that affiliation-based social categorization occurs in the SAB evaluation process, a high prestige university affiliation might diminish reliance on gender as a cue that evaluators use to judge an individual's qualifications for board membership. If this occurs, we would expect:

> *Hypothesis 1. An affiliation with a high-prestige institution has a greater effect on women scientists' likelihood of becoming a SAB member than it has on the likelihood for men.*

Role-congruity and lack-of-fit theories. Next, we consider role-congruity (Eagly et al., 1992; Eagly & Karau, 2002) and lack-of-fit (Heilman, 1983, 2001; Lyness & Heilman, 2006) theories of gender-based disadvantages faced by women aspiring to leadership positions. Like in the literature on expectation states, these theories hold that biases are grounded in gender-based stereotypes. However, in these theories, there is a different nuance to how gender stereotypes influence evaluations. Specifically, prejudice is not caused by a generalized, negative view of women. Rather, it emerges when evaluators view a woman as possessing attributes that are incongruent with those required for a specific position to which she aspires. These theories propose that women will be disadvantaged when the leadership position at stake involves traits that are culturally associated with men.

In forming a SAB, biotechnology founders often value qualities in a candidate that range from his or her depth of knowledge in specific areas of research interest to the firm, to the quality of her reputation and network, to whether or not the candidate possesses "business savvy". Indeed, both scientific distinction and business acumen may be qualifications that are incongruent with commonly held stereotypes about women faculty. For example, Larry Summers' famously controversial speech at a 2005 NBER workshop posited that the under-representation of women in tenured positions in science and engineering at top universities might result from "different availability of aptitude [between men and women] at the high end" (Bombarderi, 2005). Furthermore, based on the numerical dominance of men in other areas of the translation of university science into commercial products (e.g., filing invention disclosures, patenting, and founding a company), it may be that there are particularly strong gender stereotypes in the set of roles that link academic science to the marketplace. As a result, gender-incongruity bias may exist in SAB selection.

Similar to expectation states theory, role-congruity and lack-of-fit theories differ from supply-side explanations of the gender gap in that they draw a theoretical distinguish between scientists' objective qualifications and social perceptions of them. Role-incongruity-based biases arise from SAB selectors being unable to correctly evaluate certain qualities of women scientists when these qualities are not conventionally associated with the female gender. If, as role-congruity and lack-of-fit theories hold, gender-unfavorable social perceptions are the source of gender gap in SAB memberships, then an alteration in how a SAB evaluation is performed might lead to variation in perceptions and in the degree of gender-based biases.

Indeed, Heilman (2001) has shown that gender-stereotype-based biases are more likely to occur in settings where evaluations are informal or when information can be easily distorted during the vetting of candidates. Drawing out the implications for the context we study, this implies that an objective record of performance may matter more for women than for men as it can reduce the gap between perceived feminine (or masculine) qualities and the true qualifications of a candidate. Evidence from Lyness and Heilman's (2006) study corroborates the point. The authors examined performance evaluations and promotion rates of 448 managers and found that performance records, which provide quasi-objective evidence that demonstrates a manager's fit for a position, are more strongly associated with promotion for women managers than for men.

Examples from our field interviews with SAB scientists also support this conjecture. In describing the flow of opportunities to join SABs, a few women interviewees highlighted the impact of visible administrative appointments on the arrival of opportunities to join SABs. In contrast to their male colleagues who more often described a "steady flow" of opportunities accruing throughout their career, several women commented, "*the phone started to ring when I became [Dean, provost, director]*." One woman scientist described to us: "*About twenty invitations [to SABs] followed my getting this new [administrative] position from companies big and small…I am not sure why…certainly my lab looks at broad problems across many fields – it's an unusually diverse lab – but this is not new! I suppose with the new job I have achieved a level of stature or position that people think is interesting."* For women, such appointments confirmed their scientific and management capabilities and thereby helped them to contend for SAB positions. We expect:

> *Hypothesis 2. Evidence of scientific or management capabilities has a greater effect on women scientists' likelihood of becoming a SAB member than it has on the likelihood for men.*

In-group favoritism and social networks. A third, widely studied demand-side factor that may inhibit women's ascent to senior corporate positions is in-group favoritism. In her field study of the managers at a large company, Kanter observed that the nature of managerial tasks, often characterized by high degrees of uncertainty and discretion, creates pressure for homogeneity and conformity in the hiring and promotion process (Kanter, 1977). Candidates who are members of a minority group (e.g., women) thus face advancement hurdles in such a "bureaucratic kinship system" that reproduces the majority group's dominance of the senior ranks and authority structures in corporations (Moore, 1962).

Research in social psychology explains why in-group members are favored in highly uncertain task environments. Managers enjoy a great amount of discretion in their work and the level of discretion typically increases in the level of an organizational hierarchy. For this reason, existing staff members prefer to fill any vacant, senior positions with candidates that are deemed trustworthy. In general, individuals perceive others who share similar social backgrounds, characteristics or experiences to be more trustworthy, cooperative, and competent (Fiske, Cuddy, Glick, & Xu, 2002; Insko, Schopler, Hoyle, Dardis, & Graetz, 1990). Any predisposition to favor in-group members by an already enfranchised, majority group will lead to homosocial reproduction of the dominant coalition, especially in employment situations in which high trust is required.

In-group trust can come from two different types of homogeneity: similarity in social backgrounds and characteristics (e.g., gender), or proximity in relational space (Kanter, 1977). This implies that while gender-based homophily is likely to be at play in the selection process for senior leadership positions, proximity in social networks may serve as an alternative, and possibly counter-balancing, route for winning trust from the members of an inner circle. Indeed, network researchers have long documented that interpersonal ties generate cohesion and social obligations (Coleman, 1988). In particular, strong ties through which individuals interact with higher frequency and intensity can effectively convey trust (Reagans & McEvily, 2003), as does co-membership in a network that is rich with referrals and that can serve as an informal enforcement mechanism that encourages conformance to social norms (Macaulay 1963; Raub and Weesie 1990). In an empirical examination of these arguments in an employment context, Seidel, Polzer and Stewart (2000) found that the presence of social ties to an employer elevate a job applicant's appraised trustworthiness and performance potential in the eyes of the employer's recruiting personnel.

At the interface of industry and academe in the life sciences, network ties have been found to play a strong role in the entrepreneurial process. For example, Stuart and Ding (2006) showed that if an academic life scientist undertook a collaborative research project with a commercially active coauthor, he or she becomes much more likely than other faculty members to affiliate with for-profit companies. Consistent with previous research on the role of social networks in facilitating matches between workers and jobs (Fernandez, Castilla, & Moore, 2000; Granovetter, 1973), biotech founders in our interviews describe tapping into their contact networks to identify individuals who would be strong candidates to join a SAB. However, the male and female scientists in our interviews described different network pathways through which they obtained invitations to SABs. While the male scientists mostly have mobilized an eclectic and far-flung referral network made of strong and distal ties, the female faculty tended to rely on referrals from a limited circle of close colleagues, collaborators and students they have advised—strong, direct ties through which they had shared research projects rather than more distant social connections.

Combining insights from our field interviews, the theory of the effect of social network ties on cohesion and trust, and the theory of in-group favoritism, we conjecture that when a woman scientist has close ties with insiders in the networks of commercial science, these insiders, who have first-hand information on the woman scientist's qualifications, may help other SAB selectors to overcome the (male) in-group tendency and develop trust in the female faculty candidate. In this process, strong-tie networks may partially or fully offset in-group biases against women. We propose:

> *Hypothesis 3. Location in a strong, direct-tie network conducive to SAB opportunities has a greater effect on women scientists' likelihood of becoming a SAB member than it has on the likelihood for men.*

Hypotheses: Supply-Side Explanations for the Gender Gap

In the theories above, the gender gap in SAB participation is caused by a paucity of opportunities available to women. A contending set of explanations holds that any observed gap results from women's preferences and career choices, rather than from a bias-based dwindling in the set of opportunities available to them.

Life cycle. First, there may be life-cycle-related factors that affect the timing of women's pursuit of SAB appointment. Studies find that, relative to men, women in the full-time workforce assume greater family responsibilities (e.g., Hochschild & Maschung, 1989; Robinson, 1996). Although there are documented high rates of non-parenting and non-marriage among women faculty, survey data suggest that women faculty (but not men) with children at home work slightly fewer hours per week than their male peers (Jacobs & Winslow, 2004). In addition, a large fraction of married, female faculty members have spouses with full-time jobs (Jacobs, 2004). Therefore, female faculty may have both greater non-professional time commitments and higher household incomes than do male faculty, which may dampen women scientists' interest in allocating their time to SABs, particularly during the early career years. This supply-side, family-career tradeoff does not suggest that women will shun commercial opportunities altogether. It does, however, imply that female and male scientists will join SABs at different career stages: because they (on average) have greater family and parenting obligations, women scientists will join SABs at older ages than will male scientists. This rightward shift in the distribution of age at first joining SABs will occur if women are interested in working in these roles, but are relatively more time constrained than men in the years in which they are likely to have young children at home. If this choice-based explanation holds, we would expect to observe:

> *Hypothesis 4. Relative to men, women (on average) become SAB members at greater professional ages.*

Research preference. A second, choice-based mechanism that would generate a gender gap in SAB participation is if male and female scientists exhibit gender differences in the actual *content* of research. It is naturally the case that certain areas of scientific research have greater commercial value than do others. Moreover, it is likely that differences in commercial relevance often are knowable at the time that research projects are initiated. If women scientists on average are less interested than men in opportunities in industry, we would expect to observe a division of scientific effort: men will focus more of their research effort on questions that have potential commercial value, while women will not.

If female life scientists develop research streams that are less relevant to questions of interest to commercial enterprise, then the estimated gender gap may not imply that the genders face differences in opportunities. Specifically, as long as we assume that, in some cases at least, faculty members are aware ahead of time whether a research program may have commercial value, then the relative degree of commercial orientation in a scientist's research can be considered to be a measure of the scientist's revealed preference for commercial-sector opportunities. If, as supply-side theories suggest, the gender gap is caused by the fact that women are, for *any* reason, less interested than men in engaging with companies, we should expect to observe:

Hypothesis 5. After controlling for the commercial orientation of research choices, the magnitude of the estimated male-female gender gap in the likelihood of becoming a SAB member declines.

In particular, we will find support for hypothesis 5 if women faculty are less interested than men in roles in industry, and the respective genders set some aspects of their research agendas according to this base difference in preference. When we fail to control for the gap in level of commercial interest, it will load onto the parameter estimate for a scientist's gender. If this explanation holds, when we explicitly condition on the difference in interest—and hence the willingness to supply effort for commercial work—we should anticipate a decline in the estimated gender gap.

DATA AND METHODS

We have assembled a data archive with career histories of approximately 6,000 life scientists to empirically gauge the gender gap in SAB memberships. As we discuss next, because there are a large number of academic life scientists and a relatively small number of SAB-joining events, we employed a sampling procedure known as a "case cohort" design. This method was developed by biostatisticians (Prentice, 1986; Self & Prentice, 1988) and is commonly used in epidemiological research.

Sample and Statistical Estimator

Case-cohort design applies well in research contexts where there are few events in a large population, rendering it costly to draw a random sample containing enough events (or "failures" in the biostatistics literature) for statistical estimation. To sample in this way, the researcher first compiles the event histories of some or all of the subjects in a population that have experienced the event under examination. Next the researcher randomly draws a comparison sample, known as the "sub-cohort," from the population. The observations in the sub-cohort are then weighted in the estimation to mirror the distribution of events and non-events in the population.

To construct our dataset, we first collected information about scientific advisors of all biotechnology firms that had filed an initial public offering (IPO) prospectus (Form S-1, SB-2, or S-18) with the U.S. Securities and Exchange Commission by 2002. A total of 533 dedicated biotechnology firms headquartered in the U.S. had filed IPO prospectuses between 1972, when the first biotechnology firm went public, and January 2002, when we concluded our data collection. We were able to retrieve filings for 511 of these companies, from which we obtained biographical sketches of SAB members. In this analysis, we retained only those individuals who hold a Ph.D. degree and were in the employ of a U.S.-based university or research institution at the time they started or joined the biotech company. We identified 720 unique SAB scientists. Their first transitions to the SAB membership constitute the events we analyze.

The next step was to create a comparison set (the sub-cohort) of scientists who were eligible to become a SAB member. We did this by drawing a stratified, random sample of 13,000 doctoral degree holders listed in the UMI Proquest Digital Dissertation database, which reports the name, academic discipline, and date of all U.S. Ph.D. program graduates. The sub-cohort was constructed so that its disciplinary composition and Ph.D. year distribution matched those of the event set (e.g., 15 percent of biotechnology company advisors hold doctorates in biochemistry, so the random sample contains 15 percent Ph.D.s in biochemistry). We stratified on these two dimensions so that the individuals in the comparison cohort hailed, in exact proportions, from the specific disciplines responsible for the knowledge base of the life-science-related industries.

The members of this sample were prospectively followed from the time they earned a Ph.D. degree. We created publication histories for all scientists in our database by querying the ISI's "Web of Science" database. We then used the affiliations listed on papers to identify each scientist's employer and, assuming frequent enough publications, to track job changes.

Approximately 2,000 of the 13,000-person random sample were deleted because they did not appear in the Web of Science in any year after earning their doctoral degrees. We further deleted those who (i) published exclusively under corporate affiliations, (ii) had zero publications for a period of five consecutive years, or (iii) exited academia during the early stage of their career (those who stopped publishing within five years after receiving their Ph.D. ere likely to have only held post-doctoral positions before exiting academia). The final matched sample contains 5,946 scientists in the randomly drawn sub-cohort, augmented by the 720 event cases (SAB members), yielding a ratio of eight matched, sub-cohort sample members to one SAB event case. It has been demonstrated that a cohort-to-event ratio of 5:1 or higher results in little loss of efficiency in estimations (Breslow, Lubin, Marek, & Langholz, 1983; Self & Prentice, 1988).

We structured our data as individual-level career histories and modeled the rate of first-time transition to SAB membership. Each scientist is considered to be at risk of being appointed to a SAB at the later of her Ph.D. degree year, or 1961, when the first-ever biotechnology company was founded. All individuals who are known to be in academia and have yet to be on a SAB are right-censored (i.e., we stopped observing these individuals) at the end of January 2002 or the (assumed) age of 65. In the estimations, we used a modification of Cox's (1972) proportional hazards model that adjusts for the case-cohort sampling design. This estimator closely resembles the rare events logit (Manski & Lerman, 1977). More details of the statistical properties of the estimator can be found in Stuart and Ding (2006).

Variables

Gender and control variables. We consulted a number of data sources to create covariates at the individual-, network-, and university-levels. All time-changing variables are updated annually and are included in the regressions as one-year lags.

The *gender* of each scientific advisor and member of the matched sample was coded based on his or her first name. Gender is the primary characteristic choosers seek to convey in the selection of given names (Alford, 1988; Lieberson & Bell, 1992). Two individuals independently coded the gender of scientists in our sample and the inter-coder reliability is nearly perfect. We were able to confidently identify gender for 95 percent of the scientists in our data, either based on first names or from web searches. We have assumed that all scientists with androgynous first names are male. Our results are similar when we drop scientists with gender-ambiguous names.

We include three levels of control variables: individual, organizational and temporal. First, following previous studies of scientists' commercial activities (Azoulay, Ding, & Stuart, 2007; Shane & Khurana, 2003; Stuart & Ding, 2006), at the individual level we include three time-changing measures of scientists' human capital: *total publication count, total citation count*[2], and *inventor on patents*. Each of these is annually updated, and the publication and citation count variables are cumulative values for a scientist prior to time *t*. The patent covariate is an indicator variable that turns from 0 to 1 at the point in time when a scientist is first listed as an inventor on a patent (based on the patent application date) and remains 1 in all time periods thereafter. It is defined to be zero for the full event histories of scientists who never patent. Previous studies show that commercial science is the province of accomplished researchers, and we expect that all of these measures will increase SAB participation. Also at the individual level, we control for cohort effects and research-field effects. For the former, we include a scientist's *Ph.D. degree year*. For the latter, we include dummy variables for *Ph.D. field*.[3]

At the university-level, to control for the degree of institutional support for commercial activities, we constructed a time-changing *Employer has TTO* dummy variable, which is coded 1 in each year in which the university employing the focal scientist has an active technology transfer office. Information on founding dates for all university TTO is available from the Association of University Technology Managers (AUTM) surveys. The regressions also include

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[2] Because the citation distribution is truncated and we were only able to gather current-day citation totals for each paper tallied in 2001 rather than annual counts, it was necessary for us to impute the time path of citations to annualize the data. We did so assuming that the arrival of citations follows an exponential distribution with hazard rate (i.e., inverse mean) equal to 0.1. The bibliometric literature suggests that citations accumulate according to an exponential distribution (Redner 1998), and this is true of the typical paper in our database. We identified the specific parameter, 0.1, by manually coding 50 randomly selected papers in each of three publication years: 1970, 1980, and 1990, and then choosing the parameter that yielded the best fit to the actual time path of citations to these randomly chosen papers.

[3] The sample is stratified on Ph.D. degree year and Ph.D. field, so most of the heterogeneity in graduation cohort and scientific field is eliminated by enforcing a match between the SAB sub-sample to the random sample on these two variables. However, because individuals subsequently attrite from the sample at different rates, it is possible that there are residual, cohort and scientific field effects on the rate of joining SABs.

a period effect (*prior to 1980*), which is coded as "1" if the focal year is before 1980. This cut point was chosen because it was a watershed year for the development of the biotech industry, in large measure due to the very successful IPO of Genentech, an industry pioneer.[4]

Covariates for demand-side hypotheses. Hypothesis 1 proposes that the prestige of a scientist's university employer has a stronger, positive effect on a woman's likelihood of joining a SAB than it has for a man. We collected Gourman Report rankings of biochemistry departments for all employing institutions in the dataset, as this discipline has spawned the greatest number of commercial life scientists (and hence it is the modal discipline in the data). To capture the prestige of a scientist's employer, we collapsed the scale and measured *employer prestige* as a dummy variable set to one if the university is among the top 20.[5]

Hypothesis 2 states that documented scientific and management capabilities has a greater effect on SAB participation for female scientists. Our field interviews particularly highlighted the impact of prominent administrative posts. In the archival data, however, we were not able to gather time-changing measures of administrative positions, such as deanships. The nearest proxy we can produce for the full span of the data is the (time-changing) proportion of a focal scientist's papers for which he or she was the last author, or *percent last-authored publications*. By convention in the life sciences, the principal investigator and head of a research group is the last author on papers published by the group. Although last authors' intellectual contributions to joint research often are less than those of first authors, project leaders raise the resources that are expended in collaborative endeavors (Kempers, 2002; Shapiro, Wenger, & Shapiro, 1994). In fact, productive labs are small enterprises unto themselves: they are hierarchies staffed by technicians, graduate students, postdoctoral fellows, and at the helm, the principal investigator.

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[4] The period effect is course-grained because we already include *Ph.D. degree year* in the regressions. The proportional hazards model uses a scientist's professional age (the difference between current calendar year and her Ph.D. degree year) as the clock. With an age-based clock and Ph.D. degree year included in the models, we cannot include fine-grained period control variable (e.g., continuous calendar year or calendar year dummies). In unreported robustness tests, we have run the regressions with calendar year instead of Ph.D. year as a control in the models. This specification produces results that are almost identical to the findings reported in the paper.

[5] In unreported regressions, we performed robustness tests with different cut points. The variations included: (i) using overall graduate school rankings instead of biochemistry department rankings, (ii) using Top 10, 15, 25, 30, or 50 as the cutoff for high prestige, (iii) using categories such as 1-20, 21-50, and 51 and below or other forms of category groupings, and (iv) using continuous ranking for top 50 employers and a dummy indicating the employer is below 50 (Gourman only ranks the top 50 institutions). As one would expect, the magnitude of the prestige effect in boosting the probability of a SAB appointment decreases as the employer-prestige dummy becomes less exclusive (i.e., Top 25, 30, or 50, versus Top 20). However, interaction effects with the female variable remain largely unchanged from those we report.

Thus, scientists with many last-authored papers will possess credible management experience. We expect these scientists will elicit more SAB opportunities and that having a high proportion of last authored publications will have a particularly strong effect on the transition rate for women scientists.

Hypothesis 3 posits a differential effect of a scientist's network ties on men and women's SAB participation. A scientist's professional network can include ties to coauthors, thesis advisors, students, mentors, and others. We follow prior research on social influence among academic scientists (Azoulay, Zivin, & Wang, 2010; Moody, 2004) by measuring scientists' coauthorship networks. Assuming that co-authorships are strong ties, these gauge the potential for endorsements for commercial opportunities within each scientist's network. Although the co-authorship network admittedly is an incomplete representation of scientists' portfolio of connections, it does capture an important component of a scientist's strong-tie network, and it also offers the primary benefits of being traceable backward in time and available for the full population of academic scientists.

We create two measures from the co-authorship network. The first is an author's degree score, or the *count of co-authors*. Individuals with higher degree scores are more likely to have direct contacts that can match them to advisory opportunities. Second, we count the number of academic entrepreneurs—individuals who have previously (prior to a given year) made the transition to found or advise a biotechnology firm—with whom a focal scientist has one or more co-authored publications. We label this covariate "*count of co-authorship ties to AEs (academic entrepreneurs)*" and assume that strong connections to scientists who have already entered the commercial sphere will abet the transition of a focal scientist. Hypothesis 3 states that, relative to men, a woman faculty member's rate of joining a SAB will be more sensitive to the presence of a direct-tie network that is conducive to commercial opportunities.

Covariates for supply-side hypotheses. Hypothesis 4 asserts that if supply-side explanations have empirical leverage in explaining SAB memberships, we are likely to observe that women's age of transition to first SAB membership is older than that of men. We test this hypothesis by calculating and comparing the distributions of the time until transition to SAB membership for each gender.

Next, Hypothesis 5 posits that in regressions that account for the commercial focus of a scientist's research, the magnitude of the estimated gender gap will decline. To measure the commercial orientation of a research agenda, we utilize the publication data to generate a fine-grained gauge of the latent *research commercializability* of each scientist's research program. Specifically, we use title words in scientists' publications to identify the areas in which they have conducted research,[6] and then apply weights to theses areas based on a (endogenous-to-the-sample) measure of the extent to which other scientists working in these same areas previously have patented their scientific discoveries. Intuitively, we use the publications of scientists who have already applied for patent rights to define the benchmark for commercializable research, and then compare the research of each scientist in our dataset to this benchmark to generate a scientist-specific research commercilizability score for each scientist–year. Formally, the research commercializability score for scientist i in year t is defined:

$$Research\ Commercializability_{it} = \sum_{j=1}^{J} w^{i}_{j,t-1} \frac{n_{ijt}}{\sum_{k} n_{ikt}}$$

where $j = 1,\ldots,J$ indexes each of the scientific keywords appearing in the titles of the journal articles published by scientist i in year t. The numerator, n_{ijt}, is the number of times each of the keywords j has appeared in scientist i's articles published in year t while the denominator sums up the frequency that all key words have appeared in scientist i's articles published in the year. The term $w^{i}_{j,t-1}$ is a weight for each keyword that measures the frequency with which word j is used in the titles of articles published by scientists who have patented in year t or earlier, relative to its use in the articles of scientists who have not patented before year t. This weight measures the degree of patentability of the research key word j. More details of this measure are described in Azoulay et al. (2007).[7]

RESULTS

[6] We relied on title words in journal articles instead of journal- or author-assigned keywords because the Web of Science database did not begin to include keyword descriptors until 1992. However, the titles of biomedical research papers typically indicate the research area and the methodology used in the paper. We find high overlap between title words and keywords in the papers for which both are available.

[7] A potential alternative to *research commercializability* is to use patents themselves to proxy for commercial interest. We chose to use the commercializability score rather than a patent-based variable because we believe it better captures a scientist's choice to investigate research topics of commercial relevance. In general, scientists choose the research questions they explore. By contrast, patenting is affected by factors beyond the individual scientist's control, including the view of the university's TTO on whether a particular scientific discovery merits the costs of patent protection.

Descriptive Statistics

We begin with descriptive statistics. Notably, only 49 women are listed as scientific advisors, representing just 6.8 percent of the total number of academic scientists in this role. In comparison, almost 20 percent of the matched sample is female. A log-rank test establishes that the survivor functions for men and women are unequal ($p<0.00001$).

Insert Tables 1 & 2 about Here

Table 1 describes the gender composition in the random, matched sub-cohort and in the SAB sample, broken out by Ph.D. cohort. Consonant with published statistics (CPST, 1996; NSF, 1996), the proportion of Ph.D. degrees earned by women in the random sample increases significantly over time from 12 percent in the cohort of Ph.D.s before 1960 to 30 percent in the post-1980 cohort. Looking across all scientist cohorts, however, there are none in which women exceed 10.2 percent of the SAB sample.[8]

Table 2 reports means for the human and social capital variables at five different cross sections of scientists' tenure, broken out by gender and again including only members of the random sample. The gender gap in performance metrics in Table 2 would increase substantially if we presented these statistics for the overall dataset, instead of just for the random sub-cohort. As we will demonstrate shortly, outstanding professional achievement is highly predictive of the transition to commercial science and men comprise the vast majority of the SAB subsample. Including SAB members therefore would drive up the mean values of all measures of career success for men.

Overall Gender Gap

Multivariate regression results are presented in Table 3. Model 1 includes *Ph.D. field dummy* controls, time period (*prior to 1980*), *Ph.D. degree year* and a dummy for *employer has TTO*. In addition, the models implicitly control for a scientist's professional age (current year

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[8] Table 1 suggests that women made inroads into SAB membership between the first, second, and third cohorts in the data, and then their participation dropped off in the final (1981-1995) cohort. However, the apparent decline in female participation in the table may be misleading. Because women entered the sample later (on average) given their gradual progress in obtaining faculty appointments, the average woman in the 1981-1995 cohort is younger than the average male scientist in that cohort. Because the peak of the transition rate is at professional ages of 15 years and beyond and our data conclude in 2002, the age difference between women and men may account for the apparent decline in female participation in SABs in the last cohort. In unreported regressions, we estimate the interaction effect of a scientist's *gender* and her *Ph.D. degree year* and do not find evidence for a lower rate of transition for more recent cohorts.

minus her Ph.D. degree year). In this baseline model, gender has a strong, negative effect on the hazard of joining a SAB. Women's rate of joining a SAB is estimated to be 45 percent that of men's. Model 2 adds four covariates characterizing a scientist's research and patenting activity: *total publication count*, *total citation count*, *percent last-authored publications,* and *inventor on patents.* Not surprisingly, all four are strong, positive predictors of the likelihood of joining a SAB. Consistent with the findings of past studies (e.g., Zucker, Darby, & Brewer, 1998), the picture to emerge is that commercial science is concentrated among the scientific elite.

Insert Table 3 about Here

Model 3 adds two network variables: *count of coauthors* and *count of co-authorship ties to AEs,* the latter of which specifically gauges the extent of a scientist's connections to commercially active peers. Scientists who have a greater number of co-authors are substantially more likely to become SAB members. In addition, individuals who have co-authored with an academic entrepreneur transition at a rate about 1.31 times (= exp[0.27]) higher than those who lack connections to academic entrepreneurs. Model 4 adds the main effect of *employer prestige*, which performs as expected. Holding a position at a university with a top-20 biochemistry department accelerates the rate of joining a SAB by a factor of 2.32 (= exp[0.84]).

We now turn to the effect of gender. First, recall that the descriptive statistics in Table 2 show that women scientists have fewer patents, papers, last-authored papers, citations, and co-authors at each career stage than do men. Even after controlling for these variables and characteristics of scientists' employers, we find a large gender difference in the hazard: estimates of the effect of the gender dummy variable ranges between –0.80 in the unconditional results in model 1 to –0.49 in model 4, which controls for research and patenting activity, network ties, and employer characteristics. This translates into a per-unit-time hazard rate for male scientists that ranges between 1.63 (= 1 / exp[-0.49]) and 2.23 (= 1 / exp[-0.80]) times the transition rate for otherwise comparable women.

Tests of Demand-Side Hypotheses

Models 5-8 estimate the effect of hypothesized moderators of the gender gap, based on demand-side theories. We test our first three hypotheses by including interaction terms between the *female* dummy variable and four covariates: *employer prestige (H1)*, *percent last-authored publication (H2)*, *count of co-authors (H3)*, and *count of co-authorship ties to AEs (H3)*.

Hypothesis 1 proposes that a prestigious university affiliation partially offsets gender-based biases in inferences about competence, and thus it has a greater effect on female than on male scientists' likelihood of becoming a SAB member. We tested this hypothesis in model 5. The results fail to confirm H1: the interaction between *female* and *employer prestige* (top-20 department) is not statistically significant. This null result persists in unreported robustness tests with alternative specifications of the university prestige covariate.

We had expected to find that a high status university affiliation conveys legitimacy to scientists wishing to participate in the commercial sector, and that this certification is more important for women. The finding suggests that to the extent any such certification process may be at work, forces operating in the reverse direction offset it. One potential factor suggested by our interviewees is that a process of cumulative disadvantage for women may have developed alongside the gain in momentum of commercial science in academic circles (cf. Cole & Zuckerman, 1984). While the members of a core group of male faculty have become central actors in the network of commercial science, women have remained on the periphery of this social structure. Because male-dominated commercial networks have been centered at elite universities, men at these institutions may have enjoyed access to many opportunities distributed across this network. In other words, Hypothesis 1 may be rejected because any legitimacy-based benefit that accrues to female faculty at high-status universities is met with an equal benefit that men obtain from having prestigious employers, which is based on their favorable access to the networks of commercial science that are now anchored by the senior faculty at elite universities.

Hypothesis 2 posits that evidence of scientific or management capabilities is more positively associated with the likelihood that women join SABs than it is for men. We tested this hypothesis in model 6 and found support for it: there is a positive, statistically significant interaction effect between *female* and *percent last-authored publications*. This evidence is consistent with role-incongruity and lack-of-fit arguments about gender biases. If it is the case that gender-based stereotyping causes women to be held to a higher standard than men for recruitment to positions for which women are atypical (Lyness & Heilman, 2006), we would expect to observe—as we do—that a track record of scientific achievement and managerial experience will be more important for women than for men.

We also hypothesized that a broad direct-tie network may help women more than men in countering in-group favoritism. Models 7 and 8 in Table 3 test the differential effect of network ties on men and women's rates of joining a SAB. First is an interaction in model 7 between the *female* dummy and our primary proxy for a scientist's direct-tie professional networks, the cumulative *count of co-authors* the scientist has accrued. The positive, significant coefficient supports Hypothesis 3: the number of direct professional network ties has a stronger effect on the likelihood of joining a SAB for women than for men. The next finding of note is the large, though weakly ($p < 0.10$) significant interaction effect in model 8 between *female* and having previously co-authored papers with an academic entrepreneur (*count of co-authorship ties to AEs*). Having one more coauthor with a scientist who has previously founded or advised a company increases a male scientist's likelihood of joining a SAB by 27 percent (= exp[0.24]). In comparison, a coauthor who is an academic entrepreneur elevates a female scientist's likelihood by 70 percent (= exp[0.24+0.29]). Overall, these results support H3 that being in a direct tie network conducive to generating referrals to commercial science is particularly important for creating opportunities for women faculty.

Tests of Supply-Side Hypotheses

Turning our attention to supply-side perspectives on the gender gap, we consider whether the evidence suggests that part of the gender gap may be explained by the fact that women choose to be infrequent participants in commercial science, versus the fact that they are interested in involvement but are excluded from it due to limited opportunities. First, issues of work-family balance may lead women to choose to avoid non-essential work during the years in which their family commitments are largest. Second, we consider the possibility that *any* factor leads, on average, women to choose to do research of less commercial relevance than do men.

Insert Tables 4 about Here

Hypothesis 4 posits that if women choose to allocate more time to their families, we should expect them to delay participation in commercial opportunities until a later stage of life, when less time is committed to childcare. If this occurs, we will observe that among male and female scientists who have made the transition, there will be different distributions of the age at first joining a SAB.

The typical scientist in our sample does not engage in commercial science until relatively late in his or her career. For scientists who do join SABs, Table 4 presents the distribution, by gender, of the professional age group at which individuals join their first SAB. Among the 49 female SAB members, 42 transitioned eleven or more years after they obtained their Ph.D. with the hazard peaking in approximately the 20th year after the Ph.D., the same peak year for the male SAB scientists in our sample. Assuming that life scientists obtain their doctoral degrees at an average age of 31 (Jacobs & Winslow, 2004), this suggests that the times of highest risk are between 46 and 56 years of age. Our data further indicate that transition times are indistinguishable by gender—the mean transition age for male and female SAB scientists is 19.2 and 19.0, respectively. In addition, a two-sample Kolmogorov-Smirnov test for equality of the distribution of age at time of first SAB cannot reject the null that male and female scientists join SABs at similar career stages ($D = 0.12$, $p = 0.54$). We take this as suggestive evidence against the argument that women lack interest in pursuing SAB opportunities due to family-work-balance consideration.

While the between-gender similarity of the age distributions at the time of first transition is suggestive, it is not conclusive. In particular, if the female sample is split between women who are and who are not interested in SABs and if this split is tilted more toward the "no interest" group among women than among men, it is possible that the age of transition will be identical but, on average, women still are less interested in commercial science. To further investigate whether the gender gap in SAB membership is a matter of choice, we move to test Hypotheses 5, which posits that the estimated gender gap will decline when the regressions account for gender differences in choices about the commercial orientation of research agendas. To address this hypothesis, we introduce the *research commercializability* covariate. In Table 2 we have presented comparison of mean values of this covariate between men and women over cross sections of professional tenure. There is a moderate in magnitude but statistically significant difference in mean research commercialization between the genders.[9] The gap persists until the 20th year of professional tenure, though it narrows in tenure and disappears altogether for senior faculty.

We test Hypothesis 5 in regression models 9 and 10 in Table 3. First, *research commercializability* has the expected, positive effect on the likelihood of joining a SAB. An increase of one standard deviation in the covariate (= 0.69) is associated with a 2.49 times (= $\exp[1.32\times0.69]$) increase in the likelihood of joining a SAB. This level of significance and

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[9] *t*-tests of the mean comparisons are available upon request, though not reported Table 2.

magnitude indicate that the coefficient works as we intended to capture differences between scientists in choices about whether to focus their research on topics that are relevant to commerce. Model 9 also shows that when *research commercializability* is included in the regression, the magnitude of the gender gap does not decline. In fact, the estimated male-to-female ratio of the hazard of joining of a SAB actually increases from 1.63 (= 1 / exp[-0.49]) in model 4 to a ratio of 1.82 (= 1 / exp[-0.60]) in model 9, when we include research commercializability. In model 10, we re-estimate our regression excluding all the individual, network and university prestige covariates. Comparing the magnitude of the coefficients on *female* between models 1 and 10, we find that the estimated gender gap modestly increases from a male-to-female ratio of 2.23 (= 1 / exp[-0.80]) to 2.34 (= 1 / exp[-0.85]). Therefore, our data do not support Hypothesis 5: there is no evidence that the gender gap declines in regressions that account for gender differences in the revealed preference for commercial-sector work.

DISCUSSION AND CONCLUSION

Our research documents a gender gap and then investigates mechanisms that may account for it in university scientists' participation in private-sector scientific advisory boards. The mechanisms we examine are informed by demand-side theories emphasizing biases that create unequal opportunity structures for men and women, and supply-side theories that attribute different outcomes to heterogeneities in human capital or career preferences between the genders. Our goal has been to provide an integrated test of both families of explanations in a context in which we can identify the candidate pool for senior-level corporate positions and in which we can construct detailed, longitudinal measures of the qualifications of the individuals in the sample.

Our analyses show that women scientists are much less likely than men to join the advisory boards of for-profit biotechnology companies. With controls for scientists' professional accomplishments, social networks, employer characteristics and proxies for their interest in commercial science, we find that male scientists are almost twice as likely to join SABs. This gender gap is roughly comparable to the gap in the rate of patenting among scientists found in previous studies (Ding et al., 2006; Whittington & Smith-Doerr, 2005). Though this gap is large and in need of further investigation, our findings in one way offer hope. Whittington and Smith-

Doerr (2005) hypothesized that as commercial activities become more demanding of scientists' time and identity, female participation will decline (i.e., in the progression from patenting to advising to founding companies, we should anticipate a winnowing in female participation at each juncture). We find that the predicted gender ratio in SAB participation is roughly comparable to estimates of the gap in rates of patenting among academic scientists, which is notable because of a pivotal distinction between the two activities: the decision to patent (conditional on the filing of an invention disclosure) is solely at the discretion of the university's technology transfer office, whereas SAB membership depends on an invitation from a company. Despite this, the evidence suggests no female attrition in the progression from patenting to SAB memberships.

What general lines of theory account for the large gender gap we document? We positioned the paper as an effort to compare demand-side theories that posit biases in the workplace against supply-side theories that locate causality in individual choice. We believe that the preponderance of evidence in this article supports demand-side theories. First, the finding that past leadership positions have a much stronger effect for women than for men possibly indicates perceived incongruities between being female and leadership roles in commercial science. Likewise, the result that having many co-authors has a stronger effect on the transition rate for women faculty suggests that well-structured, strong-tie networks help women to overcome traditional out-group biases. Second and related, our archival analyses show that accounting for the revealed preference of scientists to work on commercially relevant research does not mitigate the estimate of the gender gap. These results suggest that the conditions under which the gender gap arises are more compatible with a constraint-based explanation, albeit one that may be tempered by some differences in interest in commercial science on the part of female faculty.

What do the findings of the paper suggest for policy-makers? First, a salient message is the lack of evidence to support interest-related accounts of the gender gap. Second, it is highly doubtful that the gap can be explained by the fact that male and female scientists sort into different research areas that are of varying relevance to commercial firms. Therefore, we believe that policy interventions are most likely to succeed if they are directed toward the conditions that affect *perceptions* of women's qualifications to hold senior corporate roles, especially in the eyes of the decision makers who allocate such opportunities.

In the short run, our findings point to some specific areas in which university administrators may have some leverage to remediate the gender gap. Every women we interviewed who had held a senior administrative role believed that the visibility of the office led to consulting and SAB opportunities and bolstered their legitimacy in the commercial sector. The quantitative evidence also accords with this perspective. Therefore, for women faculty who are willing to take on senior administrative assignments, such as deanships, we believe that active university policies to match women to these positions will help to create opportunities for women in commercial science.

In addition, most research universities have technology transfer offices. When they function well, these offices are reservoirs of relationships between members of the university community and industry. Our findings suggest that a direct contact networks matter more for women than men in generating opportunities in commercial science; men often attract offers based on generalized reputations, while women still may depend on referrals from close ties to match to commercial-sector opportunities. Active policies at TTOs to promote the research of women faculty and to broker connections between them and influential members of the entrepreneurship and investment communities will help women gain entry to the set of heretofore male-dominated networks in science- and technology-based industries.

We also must note a number of limitations of this research. First, in testing demand-side explanations of the allocation of SAB opportunities, our approach aims to assess biases in the allocation process by examining the conditions under which the degree of discrimination varies (cf. Petersen & Saporta, 2004). This research design has been frequently used in archival studies of workplace inequities (e.g., Lyness & Heilman, 2006). However, econometric identification of hypothesized effects based on theoretically implied contingencies naturally is less definitive than *directly* observing (in our case) the perceptions of SAB selectors. Should direct measures of evaluation records ever become available (e.g, ratings of applicants as in Petersen, Saporta, & Seidel, 2005), researchers may acquire better empirical leverage to adjudicate between demand- and supply-side theoretical explanations.

Second, in our tests of supply-side theories, we examine the timing of joining SABs and faculty members' tastes for commercial science as revealed by their bibliographic records. There are, however, many other supply-side factors that may influence the gender gap in SAB appointments, but which we are unable to explore in our archival, historical data. For example, our test of the distribution of SAB events across scientists' career cycle reveals no evidence that women faculty pursue commercial interest at a later career stage than men do. This empirical result rests on the logic that family obligations may restrict women's interest in commercial engagements during certain periods of their professional lives. In reality, it is likely that some women are deterred from entering commercial science altogether, given the oftentimes daunting task of balancing the time demands from university-related work and family commitments. Our empirical approach cannot rule out this possibility, since it merely compares the transition times among scientists who chose to become SAB members. Once again, a direct measure of scientists' willingness to supply effort may provide a more definitive empirical test, though the analyst must be sensitive to the fact that women may express less interest in commercial work simply because they (correctly or incorrectly) perceive that there are biases in the selection process that leads them to feel that they have a diminished chance of securing positions on SABs.

Indeed, whether a faculty member seeks to join a SAB will depend on many factors, ranging from his or her research tastes, desire for remuneration, career concerns, perception of the opportunity structure, and so on. The proxy we constructed, research commercializability, captures the proximity of a scientist's research program to the corpus of commercial knowledge. This covariate tells us that in terms of the production of scientific knowledge, men and women select research topics that are nearly equivalent, at least with regard to the latent commercial potential of their ideas. The proxy, however, does not incorporate other factors in the labor supply pipeline, such as scientists' willingness to promote the commercial value of their discoveries to industry. For this reason, research commercializability too is an imperfect proxy for scientists' desire to pursue SAB opportunities. In short, we suggest caution in interpreting the finding that there is a lack of support for supply-side explanations of the SAB gender gap in these data.

Future research should strive to construct supply-side indicators that combine objective data on professional histories with information that reveals the career aspirations of members of the candidate pool. For instance, the Scientists and Engineers Statistical Data System (SESTAT), a longitudinal survey administered by the National Science Foundation, collects information about respondents' education, work experience and employer characteristics. In addition, respondents in the SESTAT are surveyed about their job satisfaction and reasons for job changes. If these educational and career histories were supplemented with self-reported motivational information, this may enable cleaner estimation of gender differences in candidate's interest in supplying effort to commercial ventures. Of course, the challenge remains that individuals' interest in pursuing positions is shaped by their perception of the opportunity structure. Specifically, if women scientists feel that their odds of securing a position are low, this belief may deter them from expressions of interest. Therefore, surveys must be designed to account for these kind of subtleties, and in an ideal scenario, candidates' interest in supplying effort can be appropriately matched with information on how evaluators assess them to fully adjudicate between demand- and supply-side explanations of the gender gap in career outcomes.

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Table 1 Number of Ph.D.s Granted in the Life Sciences across Gender and Cohort

Ph.D. Cohort	Random Matched Sample		SAB Sample	
	Female	Male	Female	Male
1941-1960	54 (11.7%)	408 (88.3%)	2 (2.1%)	95 (97.9%)
1961-1970	169 (13.6%)	1070 (86.4%)	10 (4.5%)	210 (95.5%)
1971-1980	388 (18.0%)	1764 (82.0%)	30 (10.2%)	264 (89.8%)
1981-1995	419 (30.5%)	954 (69.5%)	7 (6.4%)	102 (93.6%)

Table 2: Mean Values of Human and Social Capital Covariates at Five Professional Tenure Cross-Sections, by Gender

	5th Year		10th Year		15th Year		20th Year		25th Year	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Total publication count	4.69	3.82	12.97	10.72	23.45	20.21	34.63	33.31	48.49	45.38
Citation count per paper	8.51	8.31	14.72	14.85	18.74	19.56	21.17	21.12	22.48	22.22
Pct. last-authored publication	0.12	0.10	0.22	0.17	0.29	0.22	0.34	0.27	0.38	0.30
Count of co-authors	14.66	12.66	22.68	20.79	30.45	28.22	38.62	36.18	45.10	43.58
Count of co-authorship ties to AEs	0.05	0.04	0.10	0.08	0.17	0.15	0.30	0.21	0.32	0.27
Patent count	0.03	0.02	0.08	0.05	0.21	0.07	0.38	0.11	0.48	0.16
Inventor on patent (1=Yes)	0.02	0.01	0.05	0.03	0.09	0.04	0.13	0.08	0.16	0.09
Research commercializability	0.58	0.48	0.55	0.48	0.52	0.48	0.48	0.44	0.46	0.46
N	4,153	1,021	3,156	653	2,498	456	1,949	320	1,346	199

Note: Reports the mean values for the human and social capital variables for scientists in our random, matched cohort, reported at five different levels of professional tenure (5, 10, 15, 20, and 25 years since Ph.D.), and broken out by scientists' gender.

Table 3: Case-Cohort-Adjusted Cox Regression Models of Transition to SAB

	(1)	(2)	(3)	(4)
Ph.D. field fixed effect included	Yes	Yes	Yes	Yes
Year is prior to 1980	-4.46 (0.53)**	-4.80 (0.55)**	-5.09 (0.56)**	-5.09 (0.55)**
Ph.D. degree year	-0.03 (0.01)**	-0.06 (0.01)**	-0.07 (0.01)**	-0.07 (0.01)**
Employer has TTO	0.64 (0.11)**	0.55 (0.11)**	0.53 (0.11)**	0.31 (0.12)**
Female	-0.80 (0.18)**	-0.59 (0.20)**	-0.51 (0.20)*	-0.49 (0.19)*
Total publication count		0.01 (0.001)**	-0.001 (0.001)	-0.002 (0.001)
Total citation count		0.02 (0.002)**	0.02 (0.002)**	0.01 (0.002)**
Inventor on patents		1.26 (0.14)**	1.25 (0.14)**	1.24 (0.14)**
Pct. last-authored publication		2.42 (0.24)**	2.59 (0.23)**	2.61 (0.23)**
Count of co-authors			0.004 (0.001)**	0.004 (0.001)**
Count of co-authorship ties to AEs			0.27 (0.06)**	027 (0.05)**
Employer prestige (=1 if top 20 department)				0.84 (0.12)**
Research commercializability				
Log-Likelihood	-8673.4	-8223.5	-8093.4	-8046.3
χ^2	280.70	553.62	634.81	673.23
Model d.f.	12	16	18	19

[1] Time at risk = 110,461; number of subjects = 5,946; number of events = 720.
[2] Robust standard errors in parentheses; † $p < .10$; * $p < .05$; ** $p < .01$.

Table 3: Case-Cohort-Adjusted Cox Regression Models of Transition to SAB (Continued)

	(5)	(6)	(7)	(8)	(9)	(10)
Ph.D. field fixed effect included	Yes	Yes	Yes	Yes	Yes	Yes
Year is prior to 1980	-12.79 (3.48)**	-12.98 (3.48)**	-12.62 (3.43)**	-12.61 (3.44)**	-12.50 (3.44)**	-12.28 (3.39)**
Ph.D. degree year	-0.03 (0.01)*	-0.04 (0.01)*	-0.03 (0.01)*	-0.03 (0.01)*	-0.03 (0.01)*	0.01 (0.01)
Employer has TTO	0.25 (0.13)†	0.23 (0.13)†	0.26 (0.13)*	0.26 (0.13)*	0.25 (0.13)†	0.61 (0.11)**
Female	-0.35 (0.26)	-1.16 (0.39)**	-0.77 (0.23)**	-0.77 (0.25)**	-0.60 (0.22)**	-0.85 (0.19)**
Total publication count	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	
Total citation count	0.01 (0.002)**	0.01 (0.002)**	0.01 (0.002)**	0.01 (0.002)**	0.01 (0.002)**	
Inventor on patents	1.30 (0.14)**	1.30 (0.14)**	1.29 (0.14)**	1.29 (0.14)**	1.30 (0.14)**	
Pct. last-authored publication	2.55 (0.24)**	2.43 (0.25)**	2.53 (0.24)**	2.55 (0.24)**	2.56 (0.24)**	
Count of co-authors	0.004 (0.001)**	0.004 (0.001)**	0.004 (0.001)**	0.004 (0.001)**	0.004 (0.001)**	
Count of co-authorship ties to AEs	0.25 (0.05)**	0.25 (0.05)**	0.25 (0.05)**	0.24 (0.05)**	0.25 (0.05)**	
Employer prestige (=1 if top 20 department)	0.88 (0.13)**	0.84 (0.13)**	0.84 (0.13)**	0.83 (0.13)**	0.83 (0.13)**	
Research commercializability	1.34 (0.19)**	1.35 (0.19)**	1.33 (0.18)**	1.33 (0.18)**	1.32 (0.18)**	1.27 (0.20)**
Female × Employer prestige	-0.60 (0.46)					
Female × Pct last-authored pub.		1.52 (0.73)*				
Female × Count of co-authors			0.003 (0.001)**			
Female × Count of co-authorship ties to AEs				0.29 (0.16)†		
Log-Likelihood	-7885.5	-7883.7	-7881.0	-7884.5	-7887.4	-8513.7
χ^2	696.52	694.29	968.20	700.02	694.17	200.40
Model d.f.	21	21	21	21	20	13

[1] Time at risk = 110,461; number of subjects = 5,946; number of events = 720.
[2] Robust standard errors in parentheses; † $p < .10$; * $p < .05$; ** $p < .01$.

Table 4: Distribution of First SAB Transition

Years since Ph.D.	Male	Female
1-5 years	23	1
6-10 years	86	6
11-15 years	126	9
16-20 years	155	13
21-25 years	132	11
25-30 years	74	7
31-35 years	51	2
35-40 years	24	0

Legend: reports number of scientists joining SAB for the first time. A two-sample Kolmogorov-Smirnov test for equality of the tenure distribution across gender indicates statistical equivalence.