WOMEN INVENTORS IN CONTEXT

Disparities in Patenting across Academia and Industry

KJERSTEN BUNKER WHITTINGTON
Reed College, Portland, Oregon
LAUREL SMITH-DOERR
Boston University

Explanations of productivity differences between men and women in science tend to focus on the academic sector and the individual level. This article examines how variation in organizational logic affects sex differences in scientists' commercial productivity, as measured by patenting. Using detailed data from a sample of academic and industrial life scientists working in the United States, the authors present multivariate regression models of scientific patenting. The data show that controlling for education- and career-history variables, women are less likely to patent than men. However, in biotechnology firms—industrial settings characterized by flatter, more flexible, network-based organizational structures—women scientists are more likely to become patent-holding inventors than in more hierarchically arranged organizational settings in industry or academia. The authors discuss how the organization of scientists' work settings may influence enduring disparities between men and women in science and the implications of these findings for future work.

Keywords: *organizations; work/occupations; knowledge/science*

To date, most scholarship on women in science has focused only on disparities between men and women in academic settings. In this article, we argue that such a view is limited. If one wants to more fully

AUTHORS' NOTE: *We thank Walter Powell, Cecilia Ridgeway, and Rebecca Sandefur for their helpful comments on earlier versions of this research. We are also grateful to Dana Britton, Sharon Bird, Laura Kramer, and three anonymous reviewers for their insightful comments on this manuscript. Portions of this research are based on work supported by an Association for Institutional Research dissertation fellowship, a National Bureau for Economic Research research grant, and the National Science Foundation. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the Association for Institutional Research, National Bureau for Economic Research, or National Science Foundation.*

GENDER & SOCIETY, Vol. 22 No. 2, April 2008 194-218
DOI: 10.1177/0891243207313928

understand barriers and opportunities for women in science, one needs to compare different organizational contexts in which scientists work. And if one wants to change academic conditions creatively toward promoting greater sex equity, a good way to begin is to look at other organizational models for doing science.

In this article, we contrast two basic forms of organization: hierarchy and what is sometimes called the "network form" of organization (Podolny and Page 1998; Smith-Doerr and Powell 2005). These ideal typical forms differ in several important ways: In hierarchies, the main mode of firm operation is through in-house routines, and in the network form, activity happens through interorganizational relationships; while interpersonal conflict is often resolved in hierarchies by authority ranking, in network organizations, reputation and reciprocity concerns may mute conflict; where hierarchy has a formal tone, network firms are often more open ended; and in network organizations, individuals often pursue more collective benefits rather than following rules to move individually up a hierarchical career ladder (Powell 1990).

In this article, we examine the effects that these different work settings have on sex disparities in scientists' careers. In the scientific field that is our focus—the life sciences—the emergence of the biotechnology industry in the 1970s as an arena comprising network firms affords us an important comparison. We can investigate whether this network context for women scientists sustains the same gap in scientific productivity found in the more hierarchical organizations of academia and large drug corporations where biological scientists have traditionally worked.

Considerable attention has been paid to the gendering of organizations (Acker 1990; Britton 2000). Although some work on this topic suggests that hierarchy acts to create and sustain gender inequity, other work suggests ways women workers can find equity in forms that usually favor male-typed behavior patterns. Using a national sample, Reskin and McBrier (2000) find women workers do better in larger, more bureaucratic organizations; they conclude that women are more likely to become managers when hiring practices are more formalized. Sex discrimination can certainly be mitigated by the threat of lawsuits. Sociologists have long noted that informal organization is often more important than formal rules to the actual operation of an organization. Rules can obscure gendering, as Acker (1989) revealed in her study of how "neutral" metrics for job evaluation in Oregon reinforced the "logic" for paying male jobs like technician more than female jobs like secretary. The larger and more bureaucratic a company (or academic system) is, the more room there may be for the shadow side of the organization to flourish. Our study converses with this literature by comparing very similar workers in different organizational settings and asking, Is hierarchy (and its more formal rules) or the network form better for women's productivity in science?

We focus on sex disparities in patenting across academic and industrial domains. Although some research on women in science attends to institutional structure (see, for example, Fox 2001), the focus has been conditions for academic scientists in research universities. Patents provide a new coinage that can be drawn on in careers that span industrial and academic sectors. We suggest that flatter, more flexible industrial organizations exhibit a smaller sex gap in patenting involvement than more hierarchical settings in industry or academia. In the discussion that follows, we show how previous research on the social structure of science across organizational settings leads us to this hypothesis. We highlight (in italics) several aspects of academic and industrial work settings that may be most significant.

HOW VARIATIONS IN LIFE SCIENCE SETTINGS MATTER FOR WOMEN SCIENTISTS

The Influence of Organizational Context

In the academy, head scientists compete for space and equipment, grant funding, and international reputation. Although labs are formed on the basis of collaboration, an academic professor's success is individually derived. Despite collaborating with their advisors, graduate and postdoctoral students are also looking to separate themselves as making unique contributions. Like academic scientists, industrial scientists may also maintain interests in individual achievement, and collective work in industry might also involve hierarchies of reputation. A distinguishing factor is that individual advancement is more likely to hinge on group achievement in the industry setting. In contrast to academia, industrial settings are managed based on collective science and the mutual accruing of group knowledge and resources. Hence, both academic and industrial science involves the mobilization of individuals to complete a project, but under very different circumstances of individual achievement. At the most general level, scientific industrial settings may be less internally competitive, and rewards may be more egalitarian (Rabinow 1996; Smith-Doerr 2004). We suggest that women are likely to have different experiences and opportunities regarding productivity in settings with *"individual" versus "collective" practices.* This collective structure is likely to be helpful to women not because of innate temperament but because women scientists are often marginalized (Valian 1998).

Within industry, disparities between men and women may differ in firms where work has centralized lines of authority versus firms that are more relationally based. A key difference between large, formal corporations and small, dedicated science firms is how knowledge production is organized. Hierarchical firms contain many areas of research and development under one roof, while smaller, science-based firms remain flexibly arranged to focus on a few areas of cutting-edge science. In the former, employees are responsible for small pieces of projects within large subdisciplines of the organization's focus. In the latter, scientists move among projects as the focus of the firm changes (Nohria and Berkley 1992). This collaborative environment is a feature of the day-to-day atmosphere in research-based firms. In the biotechnology industry, scientists have reported that they work toward a common goal, are less competitive internally, and have an increased emphasis on teamwork (Smith-Doerr 2005). Public discourse is populated with references to the same idea—that network firms support "teamwork" ideals and encourage the researcher to foster collaborative relationships both inside and outside the firm (e.g., Holsinger and Brandon 2001; Shook 2003).

Previous research by Smith-Doerr (2004) provides an example of how the day-to-day open communication and learning differs in life science network firms from more hierarchical settings. In her fieldwork, scientists from two biotechnology firms were at a meeting (in a mixed-sex team where one of the main project leaders was a woman), and information was flowing between members of both firms about problem solving at the lab bench. After members of one company explained to the other how to solve a difficult problem with a chemical solution, a manager—having just relocated into biotechnology from a large drug company—became concerned about leaking proprietary information. His concerns fell on deaf ears, however, and he soon learned the more collaborative norms (and the limitations of managerial pronouncements) in this new context. The contrasting approaches to science exemplified in this interaction reveal some of the distinctions between a network form and a more hierarchical one.[1]

Structurally, *teamwork environments* may enhance retention and performance among women scientists, who may have fewer personal network connections to those of influence in their field (Kanter 1977). Many organizations formed to increase the numbers of women in science have adopted the teamwork model to encourage women to stay in science. Rosser (1998), for example, discusses National Science Foundation–sponsored summer science camps for girls that focus specifically on teamwork as a tool for navigating their minority status. This research suggests that cooperation and collective problem solving in science may enhance women's experiences in science.

Network firms may provide benefits for woman scientists beyond collaborative practices and retention, however. Foremost, the flexibly arranged work environment emphasizes a more *horizontal distribution of positions and resources* within the company as a way to better anticipate the uncertain world of quickly changing research developments. Women located in organizational settings that encourage a more even distribution of positions may be better able to overcome some traditional barriers that maintain within-organization sex segregation. For example, in the life sciences, women are nearly eight times more likely to hold supervisory roles in network firms than in pharmaceutical companies (Smith-Doerr 2004). By virtue of a work design developed to manage technological advance, women scientists may find advantages in the network firm.

Women's advantages may also stem directly from their *increased management opportunities* in these work settings. Past research has shown that much of the disparities in the productivity of women scientists in the academy appears to be related to their differing job positions (Long 2001; Xie and Shauman 2003). Perhaps women's increased likelihood of holding managerial positions in networked firms allows more opportunities for collaboration and more central roles in the innovation process, including patenting. We disentangle the relationship between productivity, organizational form, and job position by analyzing the relationship between industrial setting and productivity while controlling for the supervisory positions men and women hold.

Different settings may also have different implications for the ways *collaborative networks* are realized by men and women. Many studies have shown a positive relationship between individuals' network centrality and subsequent creativity (Brass 1985; Burt 2005; Hargadon 2002). Women are less likely to have diversified research networks (Brass 1985; Ibarra 1997) and hold less central positions in academic collaboration networks (Whittington 2007). The flexible design of the network firm may provide increased opportunities for women scientists to find collaborators and obtain information on the patenting process. Indeed, research shows the sex gap in collaborative networks is significantly wider between academic scientists than between scientists in network-based life science firms and that academic women gain less productivity from central positions than their sister scientists in other locations (Whittington 2007). Women in academic settings may be more marginalized in productivity networks, while the more fluid organizational structure of the science-based firm may provide greater opportunities for collaboration.

It is tempting to relate all of the potential benefits of network organizations to their flexible structure and emphasis on teamwork. The effect of the competing incentive structures between academic and industrial science should not be understated, however. We argue that it may be the *interaction between these differing sector-level social arrangements and the flexible design of the network form* that provides the equal playing field for women in the network setting.

Scholars have yet to quantify the relationship between organizational structure and female scientists' productivity, especially within industrial locations. We test the idea that network firms are locations of increased gender equity and designate our core hypothesis as follows:

> *Hypothesis 1:* Sex disparities in scientists' patenting behavior will be less in science-based network firms than in other organizational settings.

We assess this hypothesis using multivariate models to tease out the effects of organizational context on patenting involvement. Two levels of patenting productivity are investigated: (1) any involvement and (2) the number of patents, if involved. We examine if working in a network organization reduces the sex gap in patenting while controlling for potentially intervening factors, including time since PhD, management responsibilities, and the prestige of graduate training.

Supply-side Influences

Individual decisions may also drive differences across settings. Although historically industry has been seen as less prestigious than academia, it has also provided some women with favorable workplace incentives (e.g., reasonable work weeks, higher mobility and pay) not present in the academy (Long and Fox 1995). Some scholars speculate that women scientists in the past traded prestige for family-friendly advantages in industry (Etzkowitz, Kemelgor, and Uzzi 2000). Recently, careers outside the academy have grown in prestige, and influences on men's and women's labor market decisions are changing. Smith-Doerr (2005) documents changes in the industrial sector as biotechnology firms "pull" new PhDs away from academia by promoting publishing inside the company and providing other "academic" perks.

Increased movement toward industry—in particular, to small, science-based firms—may be by choice rather than lack of academic opportunities.

Life scientists trained at elite colleges, by at least one account (Robbins-Roth 2000), are moving more frequently into biotechnology than other industry settings. If a disproportionate number of talented women versus talented men are heading into science-based firms, this might alter the differences across sectors. For this analysis, we isolate sector-level effects from "talent" by including a control for prestige of doctoral institution. The more complicated and interesting question is not about the effects of talent or agency alone but about how scientists' decisions interact with organizational structures to produce patterns. We return to this discussion of supply-side influences after presenting our results.

THE CASE: PATENTING IN THE LIFE SCIENCES

Commercial behavior can include a wide range of activities, from patenting and licensing technologies to consulting to involvement with or founding of a science-based company. We focus on patenting, which could arguably be labeled a point of entry into this domain. Patenting is important to career outcomes in industry and more recently in academia as well (Kleinman and Vallas 2006). Since the mid-1980s, there has been a dramatic upsurge in the amount of patenting in the United States and other countries (Kortum and Lerner 1998). Growth in university patenting has eclipsed that of industry during the past 20 years; the number of academic patents increased nearly eight times from 1980 to 2002 (Powell et al. 2005). Academic scientists make decisions in the face of university, department, and peer pressure about their level of involvement in commercial work (Audretsch and Stephan 1999; Slaughter and Rhoades 2004). The unanimous 2006 decision by Texas A&M University to include inventions in tenure and promotion decisions is one example of changes occurring to the reward structure of the academy. Indeed, Owen-Smith and Powell (2003, 109) suggest that commercial involvement among academic scientists represents "the appearance of a new fault line" between those who participate and those who do not. Increases in academic patenting have been particularly dramatic in the life sciences, where academic-industry relationships are common and research results translate into significant medical applications as well as substantively interesting intellectual results.

While research on patenting among scientists has grown prodigiously, studies that combine a concern with inequality and the increasing emphasis on commercial outcomes in science are rare. Productivity is one of the most commonly studied disparities between men and women scientists, however. A host of studies have found that women are less likely to publish their research than men, and there is evidence that structural positioning and resources account for much of the gap in publishing productivity (see Long 2001; Xie and Shauman 2003 for reviews). Although most previous work on sex gaps on scientific productivity has focused on publishing, initial studies in patenting show that women patent less than men in all disciplines and sectors (Whittington 2007; Whittington and Smith-Doerr 2005). Women are also less likely to combine patenting with publishing activities across sectors (Whittington forthcoming). Ding, Murray, and Stuart (2006) report that academics who collaborate with industrial scientists are more likely to patent, and their exploratory interviews indicate that women academics find it harder to make industry contacts. While some research suggests that women follow similar trajectories as men into patenting, just more slowly (Whittington and Smith-Doerr 2005), the take-away point is one of disparity. Commercial involvement may well be a new arena for gender stratification in science.

DATA AND METHOD

Data

The data for this analysis match archived career-history information from the National Institutes of Health with patent data from the U.S. Patent and Trademark Office. The data are composed of a randomly selected sample of applicants to the Cellular and Molecular Biology training grant program administered by the National Institute of General Medical Sciences, a National Institutes of Health organization. The grant application requires funded departments to list background and career information on all current and past students (at the graduate and postdoctoral levels), including current employment. We randomly sampled 7 universities from the list of 42 programs, which generated data for scientists who received their doctoral degrees from more than 100 different U.S. universities (and many universities outside the United States). Within the sampled programs, the data include the entire population of more than 3,000 past predoctoral and postdoctoral scientists' careers (including students funded by the training grants and those who were not). Application dates range from 1983 to 1995, with 1985 as the median year of doctoral receipt.

We name-matched scientists in the sample with patent data from the U.S. Patent and Trademark Office, provided by the National Bureau for Economic Research Patent Citations Data File (Hall, Jaffe, and Trajtenberg 2001). The data include all patents granted between the years 1963 and

1999 and include inventors' names, locations, patent affiliations, and patent classes and subclasses. The U.S. Patent and Trademark Office does not include inventor identification numbers across patents. We implemented a name-matching algorithm that considered inventions to be from the same person when two records have similar first, middle, and last names as well as similar city and state, assignee name, or patent primary and secondary technology class.[2]

We coded scientists as male or female using their first names. We used common name lists and background searching for those with ambiguous first names. Women constitute 32 percent of the sample, proportionate to other national samples of biological science PhDs (National Science Board 2006).

Measures

Dependent variables. The quantitative analysis consists of two parts. Because not all academic scientists patent, first involvement may be a more important measure for academics than the number of patents. In industry, however, the total number of patents often suggests productivity in the way publications do in the academy. We separate these two measures because both are important dimensions of inventing and test whether the organizational context operates on patenting volume as well as involvement.

In the first analysis, we investigate the effect of organizational context on scientists' involvement in patenting. *Involvement* is an indicator variable where a value of 1 indicates a scientist has patented at least once in the period between receiving his or her doctorate and the end of 1999.[3] In the second set of models, we investigate patenting *productivity,* using the sum total of patents in a scientist's portfolio granted between year of graduation and 1999. All models include a control for the number of years since graduation (PhD).

Tables 1 and 2 describe the variables used in the analysis. Of men and women, 28 and 14 percent, respectively, have patented. Men who have patented have an average of 4.8 patents, while the average for women inventors is 2.5 patents.

Independent variables. In addition to sex, we include employment sector and work setting measures, as well as their interaction with sex. We use the reported employer names to classify scientists as working in "industry," "academia," or "other organization" (e.g., government, nonprofit institute, or hospital).[4] We further classify scientists in the industry category as working in either (1) pharmaceutical firms, chemical corporations, or subsidiaries of pharmaceuticals (hierarchical organizations) or (2) science-based, dedicated biotechnology firms (network organizations). We draw employment classifications from a data set compiled by Powell and colleagues (2005), which is based on listings in the industry directory *Bioscan* that covers the global population of biotechnology firms and their partner organizations.

We classify scientists' workplaces by their most recent place of employment at the time of the grant application by their former lab principal investigator. It is possible that some percentage of scientists may have switched sector locations between the time their employment history is recorded and when they submit a patent application. To assess the potential bias in our sample, we performed sensitivity analyses on a random sample of 50 inventors and find that assignee names match the affiliation categories more than 80 percent of the time (41 matched correctly). We do not believe this likely small remaining percentage of sector-switching scientists presents a significant problem. Because any movement is likely to be random, it may introduce noise to the data but should not bias the coefficient estimates.

Seventy percent of the life scientists in our sample work in academia, a proportion that reflects national figures (National Science Board 2006). Table 1 suggests that industrial scientists are more likely to be involved in patenting than academic scientists. There is little difference between the patenting averages of scientists in the two types of industrial settings.

Control variables. We include several control variables to address scientists' positions and educational backgrounds. Supervisory position is measured at the most recently sampled career point. A value of 1 indicates a career position at or above assistant professor (academia) or research team leader (industry) levels.

We also include two measures of scientists' educational background: doctoral program prestige rank and an indicator of training outside of the United States. The prestige measure is based on quality and influence classifications made by the National Research Council on PhD programs in biochemistry and molecular biology in 1995. Universities rank from 1 (*most effective*) to approximately 200. We suggest that this variable is best captured in the quantitative models by viewing differences among broad categories rather than through one-unit increases in rank. Therefore, we collapse the continuous university ranking measure into three categories for this analysis—*highest ranking* (1-10), *middle ranking* (11-50), and *lower ranking* (51-200).

TABLE 1: Means and Standard Deviations for Inventor Characteristics Used in the Analysis of Engagement and Propensity to Patent, by Involvement in Patenting

Variable	*Involved in Patenting Activity (n = 225)*	*Not Involved in Patenting Activity (n = 736)*	*Total (n = 961)*
Sex			
Women	.18	.36	.32
Men[a]	.82	.64	.68
Organizational context			
Academia[a]	.54	.75	.70
Industry (all)	.28	.09	.14
Industry, pharmaceutical	.16	.04	.07
Industry, network	.12	.05	.07
Government/nonprofit research hospital	.18	.16	.16
Supervisory position			
Yes	.34	.31	.31
No[a]	.66	.69	.69
PhD university rank			
High[a]	.23	.18	.19
Middle	.53	.52	.52
Low	.24	.31	.29
Foreign PhD university			
Yes	.14	.16	.16
No[a]	.86	.84	.84
Years since PhD	16.20 (5.52)	14.40 (6.26)	14.80 (6.14)

NOTE: Columns sum to 100%, by variable. Numbers in parentheses are standard deviations.
a. Omitted category.

The prestige scale evaluates only U.S. universities. Given evidence that suggests that training at foreign universities presents an additional challenge to students who go on to work in the United States (Davis forthcoming), we place students from foreign universities in the lowest rank category for this analysis.[5] We also include an indicator variable in the models to control directly for foreign-educated scientists.

Method

We first present multivariate logistical regression models predicting whether a scientist has patented since receipt of the doctoral degree. In the second analysis, we focus on the more traditional notion of productivity—the number of patents in scientists' portfolios, using zero-truncated negative binomial count models. Negative binomial count models are commonly

TABLE 2: Means and Standard Deviations for Inventor Characteristics Used in the Analysis of Engagement and Propensity to Patent, by Sex

Variable	*Men (n = 653)*	*Women (n = 308)*	*Total (n = 961)*
Involvement in patenting			
Yes	.28	.14	.23
No	.72	.86	.76
Number of patents			
Including noninventors	1.35 (4.14)	.34 (1.14)	1.03 (3.50)
Excluding noninventors	4.83 (6.68)	2.48 (2.06)	4.39 (6.15)
Organizational context			
Academia[a]	.70	.71	.70
Industry (all)	.14	.13	.14
Industry, pharmaceutical	.08	.05	.07
Industry, network	.06	.08	.07
Government/nonprofit research hospital	.17	.15	.16
Supervisory position			
Yes	.35	.24	.31
No[a]	.65	.76	.69
PhD university rank			
High[a]	.21	.15	.19
Middle	.51	.55	.52
Low	.28	.31	.29
Foreign PhD university			
Yes	.16	.15	.16
No[a]	.84	.85	.84
Years since PhD	15.08 (6.22)	14.32 (5.92)	14.80 (6.14)

NOTE: Columns sum to 100%, by variable. Numbers in parentheses are standard deviations.
a. Omitted category.

used to predict patent count outcomes because, as is the case with our data, these distributions are typically overdispersed and right skewed. A zero-truncated negative binomial model allows us to focus solely on inventors in the sample who have patented at least once. These models are appropriate for data that have no possibility of having zeros but still follow the count-driven, negative binomial functional form.

MULTIVARIATE MODEL RESULTS

Sex and Patenting Involvement

Table 3 presents the maximum likelihood estimates of a series of six nested models. Model 1 accounts for the control variables, and model 2

TABLE 3: Maximum Likelihood Estimates from Logit Models Predicting the Probability of Scientists' Patenting ($n = 961$)

Variable	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
PhD university rank						
Middle	–0.49**	–0.42**	–0.31	–0.29	–0.34	–0.33
Low	–0.90***	–0.81***	–0.68**	–0.67**	–0.71**	–0.69**
Foreign PhD university	0.14	0.10	0.18	0.18	0.19	0.17
Years since PhD	0.06***	0.05***	0.05***	0.05***	0.05***	0.05***
Supervisory position	–0.09	–0.16	0.05	0.04	0.05	0.06
Female		–0.90***	–0.94***	–1.01***	–0.92***	–1.01***
Organizational setting						
Government/nonprofit research hospital			0.31	0.39	0.31	0.40
Industry			1.40***	1.23***		
Industry-pharmaceutical					1.60***	1.58***
Industry-network					1.18***	0.76**
Sex × Organizational Setting						
Female × Government/Nonprofit Research Hospital				–0.55		–0.55
Female × Industry				0.59		
Female × Industry-Pharmaceutical						0.09
Female × Industry-Network						1.16**
Constant	–1.48***	–1.24***	–1.61***	–1.61***	–1.59***	–1.59***
N	961	961	961	961	961	961
LR chi-square	24.86	50.08	93.18	96.40	94.53	100.12
Degrees of freedom	5	6	8	10	9	12

**$p < .05$. ***$p < .01$ (two-tailed).

adds the direct effect of sex. Models 3 and 4 include aggregated industrial context variables and their interaction with sex. Models 5 and 6 also include organizational context, but this time with disaggregated industry categories. Model 6 is the best fitting and is a statistically significant improvement on the previous nested models ($p < .1$).

The data confirm the findings of prior works, that academic women are less involved in patenting than academic men. Across all models, the coefficient for women scientists remains negative and highly significant. Models 3 and 4 include aggregated industrial context variables and their interaction with sex. Predictably, we see that scientists in industry settings are more likely to patent than their colleagues in academia. But model 4 shows there is no sex difference between industry (all work settings combined) and academia, and the inclusion of the aggregated measure does not significantly improve the fit of model 3. Models 5 and 6 also show scientists in both industry settings have an increased probability of patenting compared with those in academia. In addition, like the previous models, women scientists in academia are less likely to patent. Unlike model 4, however, the disaggregated model 6 shows that all industry settings do not have the same effect on women. Providing support to our core hypothesis, in science-based biotech firms, women experience a patenting boost that raises their probability of inventing to be equal with men scientists. The results reported in Table 3 support the hypothesis that organizational context moderates the level of disparity in involvement between men and women scientists. Women are less likely to patent than men in all settings except for industrial science–based firms, where there is no sex difference.

Based on the results of the final model, Figure 1 shows differences in the predicted probabilities of patenting for scientists working in different locations. The figure shows that the predicted probability of patenting by women scientists in hierarchical industrial settings is 62 percent that of men scientists in these settings. Scientists in academic and government and nonprofit organizations have an even greater difference in predicted probability: Women's predicted probability of patenting is 43 percent and 28 percent that of men, respectively. There is no statistically significant difference between men and women in science-based network firms, however.

These findings confirm our hypothesis that the distinction between hierarchy and the network form relates to variation in the patenting gap between men and women. The results imply support for the idea that industrial network–based settings are the most sex equal with regard to patenting. We suggest that there may be structural mechanisms for women's inventing that vary by work setting. But entering the commercial realm of patenting may be different than the volume of patent production. Controlling for

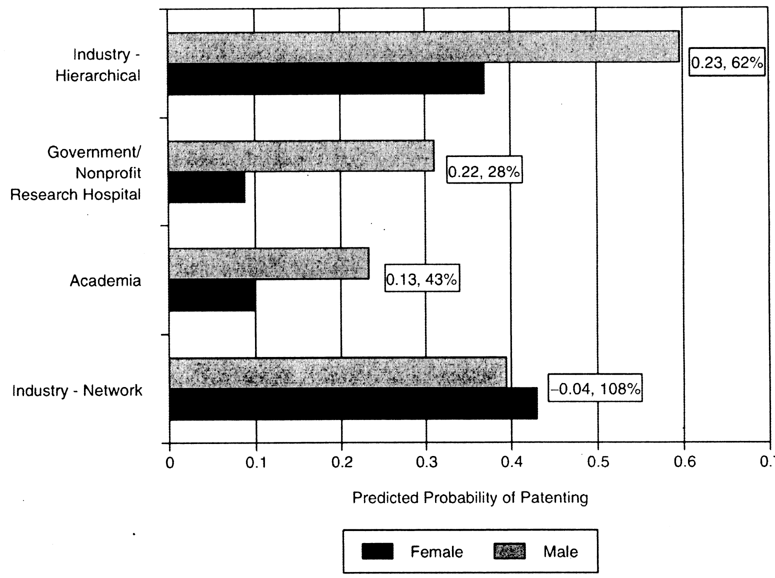

Figure 1: Predicted Probabilities of Patenting, by Sex and Sector
NOTE: Numbers in figure refer to the difference in probabilities between men and women (M-F) and the F/M predicted probability ratio (multiplied by 100), respectively.

background and job position, are science-based network firms likely to enhance the number of patents a woman scientist receives as well?

Sex and Patent Productivity

We focus on the subset of scientists who patent to investigate the effects of organizational context on number of patents, employing zero-truncated negative binomial count models. Table 4 presents maximum likelihood estimates from the same set of nested models used in the first analysis. Unlike those in the first models, however, the likelihood chi-square statistics indicate that most models do not improve on the fit of the previous model ($p > .1$). Model 3 is the most parsimonious of the set, and all following models decrease in fit with each new variable addition. These models lead us to substantially different conclusions than do the first set. It would appear that the effect of the organizational setting plays more of a role in who becomes involved in commercial work than in how much is produced.

The initial models (models 3 and 4) suggest that industry scientists are more likely to have an increased patent count than academic and institute

TABLE 4: Maximum Likelihood Estimates from Zero-truncated Negative Binomial Models Predicting Patent Counts (n = 225)

Variable	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
PhD university rank						
Middle	0.09	0.02	0.09	0.10	0.14	0.17
Low	–0.32	–0.41	–0.29	–0.28	–0.26	–0.25
Foreign PhD university	0.25	0.33	0.37	0.37	0.37	0.38
Years since PhD	0.07**	0.07***	0.06**	0.06**	0.06**	0.06**
Supervisory position	–0.32	–0.42	–0.30	–0.29	–0.33	–0.33
Female		–1.10***	–1.16***	–1.12***	–1.18***	–1.13***
Organizational setting						
Government/nonprofit research hospital			–0.01	0.03	–0.02	0.01
Industry			0.53*	0.54*		
Industry-pharmaceutical					0.40	0.37
Industry-network					0.68*	0.77*
Sex × Organizational Setting						
Female × Government/Nonprofit Research Hospital				–0.36		–0.36
Female × Industry				–0.01		
Female × Industry-Pharmaceutical						0.15
Female × Industry-Network						–0.24
Constant	–0.93	–0.36	–0.33	–0.33	–0.35	–0.38
Ln alpha	1.94***	1.52***	1.33**	1.32**	1.31**	1.31**
n	225	225	225	225	225	225
LR chi-square	9.13	20.19	24.68	24.79	25.08	25.35
Degrees of freedom	5	6	8	10	9	12

*$p < .1$. **$p < .05$. ***$p < .01$ (two-tailed).

scientists. When industry is disaggregated in models 5 and 6, however, the models suggest that the industry increase comes from inventors in science-based firms. Similar to the first analysis, women life scientists have lower patent counts than men, even after controlling for background and supervisory position. Across all models, the coefficient for women scientists is negative and significant. The models suggest that the patent count of women scientists is decreased by a factor of .30 ($e^{(-1.13)}$) compared with men, holding all other variables constant. As models 4 and 6 show, this disparity does not vary by organizational context.[6] Thus, the effect of the organizational setting appears to play a greater role in who becomes involved in patenting rather than in how much intellectual property is produced.

Patent *productivity* appears not to be influenced strongly by organizational form. Thus, the "industry advantage" for women in network-based firms seems to be restricted to mechanisms that enhance the opportunities, ability, or desire to participate in patenting, rather than the number of patents. Once involved, women patent at a decreased rate compared to men, similarly across all organizational settings. The combined results have important implications for understanding the nuances of gendered organizational contexts.

DISCUSSION AND IMPLICATIONS

We find a complicated relationship between organizational form and women scientists' patenting. The first analysis shows that an organizational context exists in which inventing, at least in initial involvement, does not exhibit sex disparity. Women scientists in small, science-based biotechnology firms are as likely to become involved in the act of patenting—a traditionally male-dominated task—as men in the same setting. Hierarchical and network-based industrial firms have similar incentives for patenting, yet these two settings show markedly different rates of involvement for women inventors. But scientists in network-based firms do not achieve complete patenting parity, as the second analysis shows that women inventors lag behind men in numbers of patents across organizational settings.

We suggest that participation in patenting is the first step toward equal productivity, however, and evidence of equality at this stage suggests flatter organizational settings enhance women's opportunities to invent. Earlier, we suggested several factors that may contribute to women's being equally likely as men to invent within science-based network firms. The work arrangements may provide men and women similar levels of research support and guidance to initiate patenting. Women may occupy a greater percentage of management positions and experience enhanced collaborative network opportunities in networked firms as opposed to hierarchical organizations. Most importantly, the flexible, flat organization of work in biotechnology settings may interact with the "collective" practices of industrial work to provide greater equality. The results speak to our initial speculations and document that the organization of network-based firms may provide a more equalizing environment for women scientists, at least at the level of initiation into the patenting realm.

Our results add to discussions of how the structure of bureaucratic institutions lead to gendered outcomes (Acker 1990; Britton 2000). Theorists like Acker have brought to light mechanisms of inequality maintained at the very foundation of workplace organization. Although past research on women in science recognizes the influence of organizational context on disparities between men and women, its focus on academic science does not allow for comparisons to assess how alternate forms of organization structure gendered outcomes. An implication of this work is that women in networked organizations may be more likely to be integrated in work teams that enable productivity. These results contrast with research that suggests that flatter, more informal organizational arrangements often lead to reduced transparency in reward allocation that can disadvantage women.

Organizational structure is probably not an either/or situation for women scientists. The very structural features that enable a large organization to excel in family-friendly policies, for example, may wind up with "mommy-tracked" female employees or significant within-firm job sex segregation. In this research, we focus on the effects of work organization for sex differences in productivity, but we hope these findings provide an impetus for future investigations to establish the mechanisms of gendered outcomes across sectors and work settings.

Understanding the features of network firms that lead to increased equality between men and women in biotechnology is important for considering the ways other kinds of organizations can enhance the participation of women scientists. Strong tradition and inertia lead to prevailing organizational configurations; significant restructuring of academic science is unlikely (and perhaps undesirable). One implication of this work, however, is that biotechnology firms—through factors such as collective rewards, interdependence, and flexible project-based work—may be better able to integrate women (and men) into leading scientific endeavors. Fostering collaborative network relationships among scientists in the academy may have important implications for women's careers and also the pursuit of knowledge.

The persistent sex gap across all organizational settings in the number of patents accrued is troubling, however, as is the generally wide disparity between men and women scientists in hierarchical settings. This analysis suggests that puzzles remain about the mechanisms by which differing organizational contexts in science affect men and women scientists. Our results could possibly reflect that women in biotech are being hired into *research* positions more comparable to men's, while other industrial settings exhibit more job segregation. Women in pharmaceutical corporations may be disproportionately located in positions without opportunities to patent. We control for some of these qualities by taking supervisory positions into account, but more detailed data on positions and resources would be useful to disentangle how biotech settings are more equitable.

Selection effects, as we suggested earlier, may also affect the *types* of scientists who choose biotechnology firms over academia and diversified industrial corporations. Women life scientists might disproportionately choose industry jobs, and the scientists most dedicated (or talented) in their basic science productivity might head to biotech. Although women in our data set constitute a larger percentage of graduates from highly ranked universities in network firms than in hierarchical settings, ranking of graduate training does not remove the direct effects of sex on patenting in the multivariate models nor prevent the network form from having an effect on involvement. Selection also cannot explain the results of the second analysis, in which all organizational settings show similar sex disparity in patent counts, despite the ranking of women's PhD institutions. Qualitative investigations of how men and women scientists enter industrial settings would be a useful complement to this research.

In addition, the inclusion of more demographic controls might reveal disparities not revealed in our models. Although we would expect men and women in similar settings to have comparable motivations to patent, differences in patenting may be greater for particular women faculty. Past research on the sex gap in academic publishing productivity examines the influence of many demographic variables as potential causes (Long and Fox 1995; Xie and Shauman 2003). Differences in background measures do not appear to explain sex disparities in publishing. In addition, interactions of sex with family characteristics such as marriage and children are weak, inconclusive, or varied (Fox 2005; Xie and Shauman 2003). Because academic patenting is not required for tenure, however, women academics may choose not to participate (or participate as much), given other work and family demands and limited resources in their academic settings. Research on patenting suggests that the largest and most relevant factor for sex differences in patenting in the academy is between women with children and everyone else (Whittington 2007). The importance of women's parenthood may be related to the necessary time or support needed to maintain the additional requirements of involvement in patenting. Further research is needed to understand the ways parenthood and other demographic factors like race operate in network and hierarchical settings.

A Life Science Effect?

We focus on firm dynamics in the life sciences, but how generalizable is this field to other scientific disciplines? Other fields exhibit similar distributions of small start-up firms and large diversified companies (e.g., information technology), and industrial practices generally rely on collaborative incentives. The length of the product development cycle in biotechnology firms is long—7 to 10 years is not uncommon—whereas fast-paced fields like computer science measure product cycles in months (Carre and Rayman 1999). The longer product development puts less time pressure on daily work and offers opportunities for increased flexibility, which may benefit women life scientists (Eaton 1999; Smith-Doerr 2004). If R&D in life science–based firms differs from R&D in other industries, the stratification dynamics may not generalize.

In addition, biotechnology firms' enhancement of sex equality may be related to the percentage of women in the discipline or work setting. The life sciences maintain a significantly higher proportion of women than physics or engineering. As Kanter (1977) noted, being one of many women is very different than being the only woman. "Token women" face barriers to the opportunity structure in any size organization. In addition to further exploring the factors that make science-based firms distinctive settings for women's productivity, future investigation is needed to gauge whether our results can be replicated in other fields, where the patenting opportunities and percentages of women vary.

CONCLUSION

We view formal policies as a complement to conditions for sex equity but suggest that less bureaucratic, horizontal distributions of work relations in network firms may better accommodate women scientists in the structure of science. Our research suggests it is important to look beyond the coarse distinctions of academic/industry science to understand how organizational settings influence sex disparities. Given the newness of patenting among mainstream academic scientists, the first patent may be the most critical for men and women scientists at this time, and evidence of differences across contexts becomes important. Our findings show room for improvement in all organizations, however. Although we make assumptions about mechanisms that may be operating across academic and industrial work settings, we present this research with the hope of stimulating empirical work on the gendered processes within organizational and sector-level influences.

Increased pressure in academia to bring in sources of private funding and to attend to the requirements of the market lies at the base of intensified attention to patenting. While we have made an argument that might be classified as a "liberal feminist" perspective, our research raises questions that could incorporate a "radical feminist" analysis of women in science (Schiebinger 1999). Women's participation in patenting, while increasingly important for their success, may be linked to larger influences on their orientation to science. Should women faculty members contribute to the commercialization of university science? Do women patent less often because of ethical or social concerns? If increased patenting leads to decreased knowledge sharing, or increased emphasis on profitability for powerful corporations rather than greater social good, then women scientists may be consciously choosing not to patent rather than being excluded from commercialization (Croissant and Smith-Doerr 2007; Metcalfe and Slaughter forthcoming). These kinds of questions are relevant and will require deeper analyses in the future.

Still, if we assume that at least some of the intellectual property will add to the greater good for human health, then we should attend to who is producing commercial life science. Understanding how men and women become differentially involved in patenting has implications for the quality of innovations on the market. Greater diversity among designers of science and technology leads to better knowledge and products (e.g., Jehn, Northcraft, and Neale 1999). For example, a recent study in the field of computer science found that technology patents of mixed-sex teams were much more likely to be cited than inventions by single-sex teams (Ashcraft and Breitzman 2006). If inventing is disproportionately stifled for women scientists, this is detrimental not just for individual careers but for society as well.

NOTES

1. There are size differentials between the average hierarchical and network firm. One survey reports that 55 percent of biotechnology companies have fewer

than 50 employees, and 90 percent employ fewer than 500 (Carre and Rayman 1999; see also Eaton 1999). The network form is not just a small firm on its way to becoming a large firm, however, although a handful of the early-established biotechnology firms have become quite large. Network firms maintain a flexible governance structure that facilitates collaborating with others to complete complementary tasks.

2. See Whittington (2007) for complete details on the matching process.

3. We do not include patents applied for prior to obtaining the PhD, and very few scientists in our sample did apply at that time ($n = 8$). In addition, this analysis records patent activity by the number of patents granted rather than the number of patents applied for (which might be viewed as a broader indicator of involvement, including "unsuccessful" or "nonpatentable" ventures). The U.S. Patent and Trademark Office does not archive information on applications once a decision has been made to grant or deny patent rights.

4. We exclude from analysis scientists who work in nonscience occupations ($n = 27$) and scientists with incomplete affiliation information (roughly 4 percent of the sample).

5. Models run with foreign universities set to the middle prestige category do not change the substantive results of this study.

6. We do not include graphs of predicted probabilities for the second analysis because of similarities across organizational forms.

REFERENCES

Acker, Joan. 1989. *Doing comparable worth: Gender, class and pay equity.* Philadelphia: Temple University Press.

———. 1990. Hierarchies, jobs, bodies: A theory of gendered organizations. *Gender & Society* 4:139-58.

Ashcraft, Catherine, and Anthony Breitzman. 2006. Who invents IT? An analysis of women's participation in information technology patenting. Report from the National Center for Women and Information Technology. http://www.ncwit.org/pdf/NCWIT_Patent_Summary_FINAL.pdf.

Audretsch, David B., and Paula Stephan. 1999. Knowledge spillovers in biotechnology: Sources and incentives. *Journal of Evolutionary Economics* 9:97-107.

Brass, Daniel J. 1985. Men's and women's networks: A study of interaction patterns and influence in an organization. *Academy of Management Journal* 28 (2): 327-43.

Britton, Dana M. 2000. The epistemology of the gendered organization. *Gender & Society* 14:418-34.

Burt, Ronald S. 2005. *Brokerage and closure: An introduction to social capital.* Oxford, UK: Oxford University Press.

Carre, Francoise, and Paula Rayman. 1999. *Professional pathways: Examining work, family, and community in the biotechnology industry.* Cambridge, MA: Radcliffe Public Policy Institute.

Croissant, Jennifer, and Laurel Smith-Doerr. 2007. Organizational contexts of science: Boundaries and relationships between university and industry. In *The handbook of science and technology studies,* edited by E. J. Hackett, O. Amsterdamska, M. Lynch, and J. Wajcman. Cambridge, MA: MIT Press.

Davis, Geoff. Forthcoming. Improving the postdoctoral experience: An empirical approach. In *The science and engineering workforce in the US,* edited by R. Freeman and D. Goroff. Chicago: NBER/University of Chicago Press.

Ding, Waverly W., Fiona Murray, and Toby E. Stuart. 2006. Gender differences in patenting in the academic life sciences. *Science* 313:665-67.

Eaton, S. C. 1999. Surprising opportunities: Gender and the structure of work in biotech firms. *Annals of the New York Academy of Sciences* 869:175-89.

Etzkowitz, Henry, Carol Kemelgor, and Brian Uzzi. 2000. *Athena unbound: The advancement of women in science and technology.* Cambridge, UK: Cambridge University Press.

Fox, Mary Frank. 2001. Women, science, and academia: Graduate education and careers. *Gender & Society* 15:654-66.

———. 2005. Gender, family characteristics, and publication productivity among scientists. *Social Studies of Science* 35:131-50.

Hall, Bronwyn H., Adam B. Jaffe, and Manuel Trajtenberg. 2001. The NBER patent citation data file: Lessons, insights and methodological tools. National Bureau for Economic Research working paper 8498.

Hargadon, Andrew. 2002. Brokering knowledge: Linking learning and innovation. *Research in Organizational Behavior* 24:41-85.

Holsinger, Leslie, and Maureen Brandon. 2001. Breaking into biotech. The American Cancer Society for Cell Biology Newsletter, March 21. www .ascb.org.

Ibarra, Herminia. 1997. Paving an alternative route: Gender differences in managerial networks. *Social Psychology Quarterly* 60 (1): 91-102.

Jehn, Karen A., Gregory B. Northcraft, and Margaret A. Neale. 1999. Why differences make a difference: A field study of diversity, conflict, and performance in workgroups. *Administrative Science Quarterly* 44 (4): 741-63.

Kanter, Rosabeth M. 1977. Some effects on proportions on group life: Skewed sex ratios and responses to token women. *American Journal of Sociology* 82:965-90.

Kleinman, Daniel Lee, and Stephen P. Vallas. 2006. Contradiction in convergence: Universities and industry in the biotechnology field. In *The new political sociology of science: Institutions, networks, and power,* edited by S. Frickel and K. Moore. Madison: University of Wisconsin Press.

Kortum, Samual, and Josh Lerner. 1998. What is behind the recent surge in patenting? *Research Policy* 28:1-22.

Long, J. Scott. 2001. *From scarcity to visibility: Gender differences in the careers of doctoral scientists and engineers.* Washington, DC: National Academy Press.

Long, J. Scott, and Mary Frank Fox. 1995. Scientific careers: Universalism and particularism. *Annual Review of Sociology* 21 (1): 45.

Metcalfe, Amy, and Sheila Slaughter. Forthcoming. The differential effects of academic capitalism on women in the academy. In *Unfinished business: Women, gender and the new challenges of higher education,* edited by J. Glazer-Raymo. Baltimore: Johns Hopkins University Press.

National Science Board. 2006. *Science and engineering indicators 2006.* Washington, DC: Government Printing Office.

Nohria, Nitin, and James Berkley. 1992. *Amgen, Inc: Planning the unplannable.* Harvard Business School Case. Cambridge, MA: Harvard Business School.

Owen-Smith, Jason, and Walter W. Powell. 2003. The expanding role of university patenting in the life sciences: Assessing the importance of experience and connectivity. *Research Policy* 32:1695-1711.

Podolny, Joel M., and Karen L. Page. 1998. Network forms of organizations. *Annual Review of Sociology* 24 (1): 57.

Powell, Walter W. 1990. Neither market nor hierarchy: Network forms of organization. *Research in Organizational Behavior* 12:295-336.

Powell, Walter W., Douglas R. White, Kenneth W. Koput, and Jason Owen-Smith. 2005. Network dynamics and field evolution: The growth of interorganizational collaboration in the life sciences. *American Journal of Sociology* 110 (4): 1132-1205.

Rabinow, Paul. 1996. *Making PCR.* Chicago: University of Chicago Press.

Reskin, Barbara, and Debra McBrier. 2000. Why not ascription? Organizations' employment of male and female managers. *American Sociological Review* 65 (2): 210-33.

Robbins-Roth, Cynthia. 2000. *From alchemy to IPO: The business of biotechnology.* Cambridge, MA: Perseus Press.

Rosser, Sue V. 1998. Applying feminist theories to women in science programs. *Signs: Journal of Women in Culture and Society* 24 (1): 171-200.

Schiebinger, Londa L. 1999. *Has feminism changed science?* Cambridge, MA: Harvard Publisher Press.

Shook, David. 2003. Using teamwork to tackle disease. *BusinessWeek,* April 24.

Slaughter, Sheila, and Gary Rhoades. 2004. *Academic capitalism and the new economy: Markets, state and higher education.* Baltimore: Johns Hopkins University Press.

Smith-Doerr, Laurel. 2004. *Women's work: Gender equality vs. hierarchy in the life sciences.* Boulder, CO: Lynne Rienner.

———. 2005. Institutionalizing the network form: How life scientists legitimate work in the biotechnology industry. *Sociological Forum* 20 (2): 271-99.

———, and Walter W. Powell. 2005. Networks and economic life. In *The handbook of economic sociology,* 2d ed., edited by N. Smelser and R. Swedberg. Princeton, NJ: Russell Sage.

Valian, Virginia. 1998. *Why so slow? The advancement of women.* Cambridge, MA: MIT Press.

Whittington, Kjersten Bunker. 2007. *Employment sectors as opportunity structures: The effects of location on male and female scientific dissemination.* Stanford, CA: Department of Sociology, Stanford University.

———. Forthcoming. Patterns of dissemination in public and private science: The effects of gender and discipline. In *The new market for scientists and engineers: The science and engineering workforce in the era of globalization,* edited by R. Freeman and D. Goroff. Chicago: University of Chicago Press for NBER/SEWP. www.nber.org.

Whittington, Kjersten Bunker, and Laurel Smith-Doerr. 2005. Gender and commercial science: Women's patenting in the life sciences. *Journal of Technology Transfer* 30 (4): 355-70.

Xie, Yu, and Kimberlee A. Shauman. 2003. *Women in science: Career processes and outcomes.* Cambridge, MA: Harvard University Press.

Kjersten Bunker Whittington is an assistant professor of sociology at Reed College. Her research focuses on the intersection of science and innovation, the scientific labor market, and social stratification. Additional work on this topic examines sex differences in productivity in light of the network structure of inventor collaborations across organizational forms.

Laurel Smith-Doerr is an associate professor of sociology at Boston University. In 2007-2008, she is on leave at the National Science Foundation as the program director of science, technology, and society. Alongside equity, she researches other tensions in the institutionalization of science including immigrants' contributions to innovation and scientists' responses to ethics requirements.