

Gender and Scientific Dissemination in Public and Private Science:  
A Multivariate and Network Approach

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Research on gender differences in productivity rarely includes scientists outside of academia, or focuses on outcomes beyond scholarly publications. This paper addresses the extent to which gender, discipline and employment sector disparities exist in the propensity to engage in publishing *and* patenting behavior. I use log linear modeling to analyze the 1990-1995 publishing and patenting activities of scientists working in three disciplines (life sciences, physical sciences, and engineering) and three employment sectors (four-year universities, government, and industry). Empirical evidence suggests that gender differences in involvement in dissemination activities cannot be attributed solely to the structural locations and organizations where women are located. In addition, the models suggest that academic *life* scientists experience a greater degree of gender disparity than industry life scientists, other things being equal. Given these results, I explore the ways in which employment sector context may differentially influence male and female scientists. Using patent data on US inventors in the life sciences across two decades, I present co-inventor collaboration networks of university and industry inventors. The network visualizations provide evidence that the structure of productivity mimics the structure of science across industry and academia, and as such have important implications for the nature of gender disparities in these work settings. I discuss these results and provide suggestions for future research.

## 1. Introduction

Information on the patenting and publishing activity of scientists and engineers has long been an interest among scholars of science and technology. Publishing transmits valuable knowledge and resources to other scientists, both in the academy and in industry, while patenting is thought to spur innovation through economic and proprietary incentives. Traditionally, scientists within academia have primarily published, shying away from pursuing economic ends through patenting or other marketable ventures, while industrial scientists have predominantly pursued commercial goals. Over the past two decades, however, federal promotion of technology transfer by universities and the increased reliance of outside business firms on academic research have created a strong link between science and technology through the commercialization of university research (Rosenberg and Nelson 1993; Cohen, Florida, and Goe 1994; Owen-Smith 2000). At the same time, in some sectors there is much greater involvement in basic research by industry (Powell and Owen-Smith 1998). Academic patenting has increased 700% since 1980 (Owen-Smith 2000), and now over 5% of all granted patents are assigned to universities (Jaffe 2000). Recent interviews by Kleinman and Vallas (2005) suggest that tenure decisions may even one day ride on scientists' patents or degree of commercial involvement. Conversely, some of the most highly cited articles in the biological sciences are published by scientists in industry (Powell et al 1996; Stephan 1996; Zucker et al 1998).

Past studies of scientific dissemination have focused largely on academic publishing, but the changing landscape of science suggests the need to broaden dissemination measures to include commercial ventures, and to consider scientists from a variety of employment sectors. In addition, while recent work provides a starting point to understand how increases in academic-industry relations shape faculty careers and identity, previous investigations leave the contemporary actions and rationale of *female* scientists largely unaddressed.

The broader focus of this work is on explaining how these changes have influenced women's careers and work in the sciences. Previous literature clearly documents that science as an

institution exists in the face of great inequality (Long and Fox 1995). The fact that women face a special series of barriers to entry and success in the realm of their scientific careers is well recognized. Women are less likely to participate in science, have less prestigious positions, and have received less recognition than their white male counterparts (Zuckerman and Cole 1975; Reskin 1977; Fox 1995). Female scientists have traditionally published (Cole 1979; Fox 1983; Cole and Zuckerman 1984; Xie and Shaumann 1998; Long 2001) and patented (Morgan et al. 2001, Bunker Whittington and Smith-Doerr 2005) less than majority males in the sciences. Studies show that at all levels, there is a great disparity in the career attainments and opportunities of female scientists (Etzkowitz et al. 2000). While past research on scientific women documents their many structural and socialized constraints (see Long and Fox, 1995, for a review of the literature), little work has investigated male and female scientists outside of the academic realm, or focused on productivity outcomes beyond publications. Assessing the effects of organizational context on multiple forms of dissemination is of great importance as scholars begin to sort out the contemporary pushes, pulls, and constraints operating on female scientists in an era where commercial and academic science are much more closely linked.

### ***Gender, Scientific Location, and Dissemination***

The persistence of gender inequities in scientific dissemination over the past two decades has received much attention among scholars of science. Publications and/or patents are generally taken as an indication of a scientist's research capabilities, and as such are an important determinant of career outcomes. Whether or not, and the degree to which, a scientist is active in publishing or patenting are particularly defining signals of her research and development goals.

Although researchers have proposed many explanations for the productivity differences between men and women, early research efforts that focused on individual status characteristics have been unable to fully account for variation in publication output (Zuckerman 1991; Long and Fox 1995; Ward and Grant 1995). Characterized most famously by Cole and Zuckerman (1984),

this inequity has traditionally been referred to as the female “productivity puzzle.” Much of the early research, however, fails to consider how resource distribution, job placement, and the structure of academic work is gendered. Organizational context likely plays an important role in gender equality, as successful scientific work relies on equal access to facilities and funds, available help, and a supportive research environment (Fox 2000). Indeed, in a recent study, Xie and Shaumann (1998) are able to render much of the direct effects of gender on publication productivity insignificant by taking into account organizational and family context. They suggest that the traditional “productivity puzzle” should be replaced with a new puzzle to explain differences in personal and structural characteristics.

By focusing solely on faculty members, however, previous research neglects a significant part of the scientific population, and also an understanding of how the existing organization of academic life compares with that of other science and technology sectors. While numerous studies have contributed to our understanding of inequality among scientists, most have concentrated on either one type of science or another, combined similar sciences together (often in an attempt to increase the small percentages of women in their sample), or controlled for discipline or employment sector effects irrespective of their joint interaction with gender. In addition, few analyses have concentrated on how these contexts may affect male and female scientists differentially (Fox 1985).

This issue is particularly important as there has been a slow but steady increase in the percentage of scientists working beyond the academic sector (Long 2001). Historically, industry has been seen as separate from and less prestigious than academia (Zuckerman 1970), yet it has also provided some women with favorable workplace incentives (such as flexibility and higher mobility) not present in the academy (Long and Fox 1995; Aisenberg and Harrington 1988). In the past there has been speculation that women make a tradeoff in prestige for the slight advantages available in industry (Etzkowitz 2000). Recently, however, scholars are recognizing that careers outside the academy are growing in numbers and in prestige, as well as offering increased

incentives for those women who choose to leave the academy (Smith-Doerr 2004b; Rabinow 1996). Growth in university-industry relations has increased contact between academic and industrial researchers, altering the dissemination and productivity paths of scientists outside of academia. Whether this changing context has had a differential effect on male and female scientists is unclear, as measures of inequality among industrial scientists are lacking. Recent work by Smith-Doerr (2004a) shows that male and female scientists tend to hold comparable management positions in industrial biotechnology firms. Past research by Long, Allison and McGinnis (1993) shows a causal relationship between academic rank and dissemination, with higher-producing scientists receiving more returns to career advance. We might expect that similar processes may be acting upon industrial scientists, and as such, gender differences in involvement among them may be smaller than their academic counterparts. To the extent that gender differences in research productivity are the result of the different positions women hold, rather than differences in capability or motivation, one can expect the gender gap in dissemination involvement to vary across organizational contexts and scientific programs as well.

### ***Gender and Patenting***

It is important to consider the effects of organizational context on gender disparities for not just publishing, but patenting activities as well. While commercial activity is often a given in industrial firms, research by Owen-Smith and Powell (2001) suggests that commercial involvement among academic scientists represents “the appearance of a new fault line” between those involved and those who choose not to participate (109). Like publishing, women tend to patent less than their male counterparts (Morgan et al. 2001; Bunker Whittington and Smith-Doerr 2005), but the ways in which commercial dissemination may represent a new arena for gender disparities remain largely unexplored.

This work builds upon my previous research with Smith-Doerr (2005), which finds gender disparities in commercialization among life scientists to vary across work settings. Using a

combination of career history data and patenting information for a sample of life scientists across a period of two decades, we find that female scientists engage in and produce less commercial work than male scientists, and that the degree of gender disparity remains relatively constant across time.<sup>1</sup> Importantly, however, gender differences in commercial involvement are greatest in academia, where the percentage of men involved more than doubles that of women. Although women patent less than men in industry as well, it is a much smaller difference.

This previous research provides a starting place to address how dissemination varies across sector, and has several implications for future work. First, the focus on a sample of life scientists leaves the broader context of discipline unaddressed. In addition, the descriptive statistics do not move beyond simple relationships between patenting and sector. Lastly, I have not focused on how these results apply to publishing behavior as well. It would be preferable to know the extent to which these findings are generalizable across disciplines and work settings, and whether they apply to multiple dissemination outcomes.

The present work tackles these issues with a two-part analysis. The first analysis addresses the relationship between organizational context and gender on a macro-level across 3 disciplines and 3 employment sectors. I present log linear models of patenting and publishing activity using a nationally representative sample of doctoral recipients in several sectors and disciplines. I investigate the extent to which employment sector differences exist in a national population of scientists and engineers from various disciplines, and for publishing as well as patenting. Specifically, I address the following questions: Does male and female propensity to patent and publish vary by type of science and employment sector? Is there a gender gap after controlling for the distribution of males and females into lower or higher producing sciences and sectors? In sum, what is the association between gender, discipline, employment sector, and involvement in scientific dissemination?

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<sup>1</sup> The quality and impact of women's commercial work remains the same or better than that of male scientists, however.

In the second part I explore the ways in which various organizational contexts may differentially influence male and female scientists, highlighting the specific case of life scientists working in the Boston region, one of the most active and fertile areas in the world for biotechnology (Owen-Smith and Powell 2004, Porter, Bunker Whittington and Powell 2005). Using NBER patent data on US inventors across time, I present network visualizations that depict co-inventor collaborations of university and industry life science inventors. I suggest how the structure of science within each sector may contribute to existing trends in gender differences in productivity. Combined, the two analyses have important implications for the effects of organizational context on productivity.

## **2. Analysis 1**

### ***Survey Data and Measures***

To examine the relationship between scientific dissemination and gender, type of science, and employment sector at the most macro level, I analyze data from the 1995 National Science Foundation's Survey of Doctoral Recipients (SDR).<sup>2</sup> The SDR incorporates a complex survey design that stratifies respondents by scientific discipline, employment sector, receipt of a doctoral degree, and demographic variables. When weighted, SDR data characterizes a nationally representative population of individuals trained and/or working as scientists or engineers between 1990 and 1995.<sup>3</sup> The SDR includes scientists working across a variety of employment sectors and disciplines, making it a useful dataset to address these research questions.

For this analysis I focus only on scientists whose principal work responsibilities include research and development. The SDR asked respondents to indicate the primary and secondary work activities on which they "spend the most hours during a typical work week."<sup>4</sup> I restrict the

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<sup>2</sup> The SDR population consists of all individuals under the age of 76 who received a research doctorate in science or engineering from a United States institution prior to June 1994 and who resided in the United States as of April 1995.

<sup>3</sup> All results and data presented here incorporate *weighted* sample statistics.

<sup>4</sup> Scientists could choose from the following work activities: 1) accounting, 2) applied research, 3) basic research, 4) computer applications, programming, or system development, 5) development, 6) design of equipment, processes or



sample of scientists to those who listed applied and basic research, development or design as their *primary* work activity in order to reduce the potential of finding dissemination variation due to differences among scientists' primary work activities. Limiting the sample to scientists who indicate that the *majority* of their time is spent on research and development helps to address concerns over unequal allotments of work activities among male and female scientists in similar positions (for example, variations in teaching loads or committees, management responsibilities, etc).<sup>5</sup>

### ***Measures***

Dissemination activity is measured by combining responses to two survey questions. Scientists were asked whether or not they had been named as an inventor on 1) a U.S. patent application and 2) as an author or co-author on a peer-reviewed published paper, in the past five years. These two variables were combined to make one variable with four categories: 1) respondent neither published nor patented, 2) respondent published, but did not patent, 3) respondent patented, but did not publish, and 4) respondent both published and patented.<sup>6</sup>

Scientists are classified by what NSF terms "major employment sector," that is, two-year colleges, four-year colleges, government, or business/industry. Institutions designated as four-year colleges include baccalaureate and master's institutions, and Research I and II universities. The industrial sector includes private, for-profit companies, as well as scientists who are self-employed. Most scientists within the government sector are federal workers; however, state and local

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models, 7) employee relations including recruitment, training, or personal development, 8) managing and supervising, 9) production or operations, 10) professional services, 11) sales, purchasing, marketing, customer service, or public relations, 11) quality assurance, 12) teaching, or 13) other.

<sup>5</sup> In addition, only scientists who are working full time are included in the sample. Part-time scientists may not have an equal opportunity to publish and patent to the same degree as compared to their full-time counterparts. The percentage of scientists who work part time while engaging in research and development as a primary work activity is small (3.6% of the sample (N = 636)). Models run with and without part-time scientists do not differ qualitatively. All coefficients have the same sign and significance, and magnitudes are negligibly different.

<sup>6</sup> Across and within sectors, disciplines vary in their propensity to publish and patent. Using a measure of publications and patents accrued over a period of five years may seem stringent for some fields and too lengthy for others. Because this analysis controls for distributions across discipline and sector, however, it is possible to compare scientists within fields and sectors without having to choose a global average across fields.

government scientists are included as well. For the purposes of this paper, however, government is included largely as a control.

In addition, scientists are placed in one of six disciplines according to the type of science they perform in their current job. These categories are computer and mathematical sciences, life sciences, physical sciences, social sciences, engineering, and non-scientific occupations. For this analysis, I excluded scientists who worked at two-year colleges, as well as those located in computer sciences, the social sciences or in non-science or non-engineering disciplines. Theoretically, I am mainly concerned with scientific occupations that produce research that is potentially patentable as well as publishable. Although publications may be common, non-scientific occupations and the social sciences are not oriented towards commercialization in the same way other sciences are (for example, only 0.4% (N=7) of social scientists in the sample patent).<sup>7</sup> Computer science faces a different issue. Its path-breaking technology moves at a much faster pace in both discovery and development than other sciences. As such, transmission of knowledge in computer science frequently requires routes that are much faster than the average two-year lag between a filed and issued patent. Often computer science and similar fields resort to other methods of dissemination such as trade secrets, publishing, or copyright to preserve property rights and/or transmit new knowledge.

Once all variables and constraints are taken into account, the final sample for this analysis consists of 10,144 scientists, 16.5% of whom are female. There are no missing data.

### ***Survey Statistics***

Table 1 presents weighted summary statistics on the sample's participation in publishing and patenting activities, broken down by employment sector. The table shows that scientists vary

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<sup>7</sup> However, because women represent a greater percentage of social and behavioral scientists than they do in the natural, physical, and engineering sciences, it is important to know how the exclusion of this group may bias the analysis. The majority of social scientists publish only or disseminate nothing (54.5% and 44.7%, respectively), and differences between men and women are small (although higher in academia than industry). Because very few members of these groups have a propensity to patent, many cells in the contingency table are small in count or have no activity at all. This sparseness ultimately causes methodological problems in the stability of the log linear models that cannot be resolved. While instable, models run with and without social scientists yield coefficients similar in sign, magnitude, and significance, and the substantive findings of this work remain the same.

in their propensity to publish and patent. Involvement in commercial activity remains an activity pursued by a minority of the scientific population. The majority of all scientists, male and female, tend to have *only* published, if at all, between 1990 and 1995. Approximately 25% of the national population of scientific doctorates indicated that they had patented between 1990 and 1995. This percentage is heavily skewed by the higher rates of industrial patenting, however. About 15% of university scientists had patented in the period leading up to 1995, as compared with 39% of industrial scientists.<sup>8</sup>

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TABLE 1 ABOUT HERE  
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As Table 1 shows, male and female scientists have similar preferences for patenting and publishing, although female participation differs from that of male scientists in a few notable areas. First, a higher percentage of women than men only published. This is true in both academic and industrial settings, although the largest difference among men and women in publishing only occurs in industry. In addition, the 1995 SDR data echoes previous findings of commercial participation, that female scientists participate less in patenting than male scientists (Morgan et al. 2001; Bunker Whittington and Smith-Doerr 2005). Approximately 13% of women as compared with 21% of men patented by 1995. These sample statistics suggest the same result as that of the life science sample mentioned above – that the majority of this disparity comes from the academic sector. The proportion of male scientists involved in patenting is about twice that of female academic scientists. Industrial male and female scientists, on the other hand, appear to be more similar regarding commercialization. Women are only slightly less likely to participate in both patenting and publishing activities (29% versus 25%).

The above descriptive statistics suggest the need to further investigate the effects of male and female locations on dissemination activity. While women are less likely to engage in

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<sup>8</sup> The three disciplines also vary somewhat in their propensity to publish and patent. Engineers are more likely than life or physical scientists to patent in the university (24% versus 13% and 12%, respectively), and physical scientists are slightly more likely to patent in industry than engineers and life scientists (46% versus 38% and 31%, respectively).

commercial behavior, once sorted by sector the dissemination trends among male and female scientists diverge. What effect does location have on female dissemination activity once the distribution of women and men across disciplines is addressed? Moreover, how do documented gender disparities in dissemination change after accounting for location and organizational context? I turn to these questions below.

### ***Survey Models and Methods of Estimation***

To study publishing and patenting behavior by gender, discipline, and employment sector, I use log linear models that identify the associations among these variables independent of the marginal distributions of males and females across sciences and sectors. The primary objective of log linear analysis is to determine if the distribution of counts among the cells of a table have an underlying structure. With the case of gender and dissemination, we can make several predictions about how the distribution of women and men in sciences and sectors may shape the degree to which women participate in various scientific dissemination activities.

This methodology is both useful and necessary for this type of analysis because it permits the modeling of relationships between two or more categorical variables. Rather than specify only one outcome variable and several explanatory ones, log linear modeling allows one to study the association patterns among all of the variables. This method is especially practical for this analysis because it allows for the complexities of association linkages among *all* of the variables, rather than looking solely at the effects of each variable on a single outcome. Log linear modeling accounts for the *inter-relationships* between science, sector, gender and dissemination. Importantly, log linear modeling provides a method by which to estimate the effects of multiple-order interactions in conjunction with and controlling for the effects of other multiple-order interactions.<sup>9</sup>

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<sup>9</sup> One possible reason for the lack of research addressing joint program and sector effects on gender and dissemination is the methodological difficulty of multiple third-order interactions. Log linear analysis provides a way to account for these multi-level interactions, simultaneously.

To examine these relationships, the scientific dissemination table was cross-classified by gender, employment sector, and discipline. There are 72 cells in the dataset (4 (dissemination) x 2 (gender) x 3 (employment sector) x 3 (discipline)). Table 2 presents the seven nested models in this analysis. In simplified hierarchical terms, they can be presented as follows:

- (1)  $\text{Log}(U) = \text{Constant}$
- (2)  $\text{Log}(U) = \text{Model 1} + \text{patpub} + \text{gender} + \text{discipline} + \text{empsectr}$
- (3)  $\text{Log}(U) = \text{Model 2} + \text{patpub} \times \text{discipline} + \text{patpub} \times \text{empsectr} + \text{discipline} \times \text{empsectr} + \text{patpub} \times \text{discipline} \times \text{empsectr}$
- (4)  $\text{Log}(U) = \text{Model 3} + \text{gender} \times \text{patpub}$
- (5)  $\text{Log}(U) = \text{Model 4} + \text{gender} \times \text{empsectr} \times \text{discipline}$
- (6)  $\text{Log}(U) = \text{Model 5} + \text{gender} \times \text{patpub} \times \text{discipline} + \text{gender} \times \text{patpub} \times \text{discipline}$
- (7)  $\text{Log}(U) = \text{Model 6} + \text{gender} \times \text{patpub} \times \text{empsectr} \times \text{discipline}$

where only the highest-order terms are listed, and the lower-order terms are assumed. Here  $U$  is the predicted number of scientists, *discipline* is the scientific discipline, *empsectr* is the employment sector, *patpub* is patenting and publishing activity, and *gender* is the whether the respondent is male or female.

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TABLE 2 ABOUT HERE  
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### ***Model Results***

Table 2 presents the results from a series of log linear models, in which the associations between gender, discipline, employment sector, and dissemination activity are estimated from the data. Models 1 and 2 in Table 2 account for the constant-only model and the direct effects of the variables. The direct effects model accounts for dissemination, gender, type of science, and employment sector without making any assumptions about the relationships between the variables. The likelihood-ratio (LR) chi-square for Model 2 is 4,903 with 63 degrees of freedom. As is to be expected, this model fits very poorly by both the likelihood ratio test and by the Bayesian

Information Criterion (BIC).<sup>10</sup> This is not surprising because Model 2 makes the unlikely assumption that scientists are distributed evenly across sectors and programs, and disseminate equally without effects from these areas.

The third model adds 28 terms to account for the effects of differential dissemination rates across disciplines and employment sectors, and the distribution of scientists across combinations of fields and sectors. Model 3 considerably reduces the goodness-of-fit chi-square from 4,903 to 1,085, but it still does not pass the likelihood ratio test or meet the BIC criterion. Model 4 adds three more terms to the existing model to account for the effects of gender on dissemination. This additional factor reduces the goodness-of-fit chi-square (from 1,085 to 891), and significantly improves the fit of the model, but it is not yet a well-fitting model by either LR or BIC criteria. This improvement, however, indicates the presence of differential dissemination trends among the sexes.

Model 5 includes 8 additional terms for the three-way interaction between gender, employment sector, and discipline, which accounts for the distribution of women across sectors and sciences. The addition of these terms drastically reduces the goodness-of-fit chi-square, from 891 to 44. With a p value of 0.001, this model's significance gets closer to, but not above, the 5% probability threshold needed to reject the LR test. Model 5 is the first model that achieves a good fit by the BIC criterion (-177.7). The significant increase in fit indicates the importance of accounting for the different locations of male and female scientists when analyzing dissemination. The significance of Model 5 suggests that aside from the uneven distribution of scientists across sectors and disciplines (Model 3), *female* scientists have their own unique pattern of location.

Apart from gender distribution, however, disciplines and sectors may have differential effects on male and female dissemination. The next two models test whether or not gender

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<sup>10</sup> The BIC calculates the goodness of fit in terms of how the data compares to the saturated model. When the BIC is negative, it is considered better than the saturated model (Raftery 1986). Although generally accepted in the literature as a satisfactory measure of a model's goodness of fit, the BIC measure is considerably less stringent than the likelihood ratio test. For this reason, the results of both tests are reported for each of the models.

disparities change across disciplines or sectors. Model 6 adds two three-way interactions between gender, dissemination, and discipline and gender, dissemination and employment sector. This model improves on the previous one with a goodness of fit chi-square of 24.8 and 12 degrees of freedom. The significant improvement of this model over the last suggests that there is a differential gender effect operating among disciplines and sectors. The model's p-value, however, is 0.02, slightly below the 0.05 threshold needed to reject the LR test. This result indicates that the saturated model – one that includes associations between all variables in the model - is most appropriate for this data.<sup>11</sup> Model 7 incorporates the saturated model by including an interaction between dissemination, gender, discipline, and employment sector.

Model 7 is the final and best-fitting model of this analysis, indicating that male and female scientists disseminate differently across sectors and disciplines, other things being equal.<sup>12</sup> Model 7 also documents the persistent presence of direct gender effects on dissemination. Interaction terms between gender and dissemination activity remain significant in the final model despite accounting for the distribution of women across sciences (Model 5) and gendered employment sector and discipline effects on dissemination (Models 6 and 7).

Changes in the coefficients for the interaction between gender and dissemination across models are telling. Before controlling for the distribution of women across sectors and sciences, women are more likely to publish than men, and only slightly less likely to engage in dual dissemination. The final model portrays a very different story, one in which women are at a clear disadvantage. The fact that the coefficients become more negative with the addition of female distribution controls suggests that women tend to be located in sciences and sectors that are less

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<sup>11</sup> The significance of the saturated model indicates that a unique relationship exists between all four variables in the analysis, rather than an over-arching simpler trend based on combinations of the four. In laymen's terms, this means that gender and dissemination likely vary by both discipline and employment sector, concurrently, rather than just discipline or sector alone.

<sup>12</sup> Although Model 5 is best fitting by BIC standards, I choose the best fitting model by the more stringent likelihood ratio test. I make this decision primarily because the BIC criterion, in which models with BIC less than zero are preferred to the saturated model, is far easier to satisfy than the more stringent likelihood ratio test of model fit. In addition, there have been some critiques of the BIC's ability to correctly take into account the sample size of the hypotheses in question (Weakliem 1999).

disadvantaging. When controlling for this distribution, however, we see that independent of sector and science, women experience disparities between themselves and their male counterparts.

As predicted, results indicate that the propensity to publish and patent varies with gender as well as discipline and employment sector. Including interactions between 1) gender and dissemination, 2) gender, discipline, and employment sector, and 3) gender, employment sector, and dissemination greatly improve the fit of the model. Despite accounting for the distribution of scientists across fields, the persistence of significant interaction effects between gender and dissemination indicates that the location of female scientists alone does not explain patenting and publishing differences between male and female scientists. Furthermore, gender effects on dissemination operate uniquely within disciplines and sectors, and the best fitting model includes interactions between all four variables.

The final model coefficients suggest substantial discipline, sector, and gender effects on dissemination, yet further analysis is needed to discern the relationship among all interactions combined. From these results, it is possible to construct comparisons of log odds across and within groups to investigate the implications of the final model. Table 3 presents the log odds and odds ratios of dissemination between males and females across academia and industry, broken down by discipline.<sup>13</sup>

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TABLE 3 ABOUT HERE  
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***Odds Ratios***

The raw percentages in the earlier descriptive statistics suggest that gender disparities may vary by employment sector. In particular, industry settings appear to be more gender equal with regard to both patenting and publishing, and industrial women appear to engage in publishing behavior *more* than industrial men. The log linear models echo this finding, yet with an important caveat – only for the life sciences. Due to significant, positive interactions between industry,

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<sup>13</sup> Table A1 in the appendix presents the log linear coefficients from the final model.



gender, and dissemination, female industrial scientists in the life sciences are *equally* likely to publish as male scientists. Table 3 shows that male life scientists in academia have approximately 3.5 times higher odds of publishing and patenting than life science female academics ( $p < .001$ ), but there is no disparity between male and female life scientists in industry. Thus, the models show significant gender disparities among life scientists in the academic sector, whereas male and female industrial life scientists disseminate equally.

Table 3 also shows that uniform employment sector effects are not apparent in the other disciplines. Male and female engineering and physical scientists in the academic setting do not exhibit statistically significant gender differences in involvement. The results are similar for industrial engineers, but male physical scientists in industry are approximately twice as likely to patent and publish than female physical scientists in industry.

Thus, it appears that organizational context plays a highly significant role in addressing the gender disparity seen in the descriptive statistics in these models. In particular, the trends seen in the raw data stem from those exhibited by scientists in the *life* sciences. Engineers are remarkably gender equal with regard to involvement in dissemination activities, and only in industry do male and female physical scientists differ with regard to dual dissemination outcomes.

### ***Implications of the Survey Models***

The national sample sheds light on the degree to which the sector-level differences seen in my previous research extend beyond the life sciences to other disciplines and sectors. At least on a macro-scale, broad-based sector effects appear to be most prominent for scientists in the life sciences. Why do gender disparities in the life sciences vary so clearly across sectors lines? Or conversely, what factors in the academic and industrial settings of engineering, for example, maintain a similar level of gender disparity across sectors?

One way in which the life sciences differ from the physical sciences and engineering is in the proportion of women scientists working in the field. The life sciences have the highest female

composition of the science and engineering disciplines in both industry and academia. Previous research has heralded the inroads women have been able to make in the life sciences, and presented it as one of the more female-friendly disciplines. In contrast, women continue to remain a very low proportion of physical scientists and engineers. Whereas the proportion of women in this sample in the life sciences is 27%, they make up only 10% and 5% of the physical sciences and engineering, respectively. The relative equality of men and women in sciences of extremely low female proportion may reflect that, either by choice or necessity, women tend to more closely resemble the men that dictate the norms of their working environments. Potential evidence for this speculation is that the models show that women are more likely to engage in publishing and patenting behavior than men in academic engineering settings. This activity may be related to discriminatory factors and/or selection effects (the few women in the engineering have to “outperform” men in order to continue on a similar path, for example) that may matter much less in environments where a higher percentage of women work. Although this explanation seems plausible, it is difficult to demonstrate quantitatively, as the past two decades of gender research have attested.

I suggest that an additional factor may be important to consider when looking at large scale sector-level effects – organizational form. The structure of industrial firms differs from that of academic settings, and industry context may vary across disciplines as well. Organizational work settings within an industrial sector are not necessarily comparable; they may vary in terms of whether they are more hierarchical or relational (Powell 1990; Sabel 1994). The life science industry, in particular, is notable for its abundance of small, “dedicated biotechnology firms” (DBFs) – research-intensive organizations primarily concentrating on genetic engineering and molecular biology for human therapeutic and diagnostic applications (Powell et al. 1996). Increasingly, life scientists in industry must decide whether to work for large diversified pharmaceutical corporations or smaller “start-up” DBF organizations. Smith-Doerr’s research (2004a) speaks to the relevance of gender in these two very different industrial work settings. Specifically, she finds equality in the types of management positions male and female scientists

hold in small DBF organizations, but finds greater gender disparities among those in corporate labs and in academia. My additional research with Smith-Doerr using the same sample of life scientists also shows evidence that female scientists perform especially well in these science-based types of organizations (Bunker Whittington and Smith-Doerr 2006). As in the national sample results shown above, our multivariate analyses predicting involvement in commercial activity demonstrate that female life scientists in industry are equally likely to become involved in patenting activity as industrial males, while male academics are over twice as likely to patent than female academics. Importantly, however, the models suggest that this sector difference is limited by type of industrial organization – only in small, dedicated biotechnology firms. Life scientists working in industry for large, multinational companies are not privy to this “industry advantage”. Hence, it appears that the commercial activity of female scientists located in dedicated life science startups may be driving the sector-level differences seen in the log linear models.

Clearly there is something unique about industrial DBF work settings. If the culture and organization of scientific work across these varied work settings matters for predicting gender disparity in productivity, the structure of science within smaller, dedicated biotechnology firms may operate as an opportunity structure for gender equality in dissemination. In the next section, I present network visualizations of academic and industrial inventors in biotechnology to examine the structure of science across these two work settings. I compile connections among co-inventors through US patent activity across a period of two decades, and present network graphs of the scientific community in both sectors. Investigating collaboration networks allows me to visualize otherwise intangible differences in sector-level structure, and make inferences about the degree to which women and men may be affected by critical differences in organizational context. In addition, collaboration networks permit me to address how the structure of “informal” personal relationships among inventors speaks to the broader arrangement of the production of knowledge across biotechnology firms and the academy.

### 3. Analysis 2

#### *Network Data*

The network data consist of inventor-level information from United States patents filed between 1976 and 1998 from the academic and industrial sectors. To gauge the degree of female and male commercialization in *industry*, data are available from Powell et. al (2005) on 482 public and private biotechnology firms. Powell et al. collected the data on firms and firm networks from *Bioscan*, an industry publication that reports information on firms and their formal agreements. *Bioscan* includes nearly the entire population of biotechnology firms in existence between 1988 and 1998.<sup>14</sup> The *academic* sample consists of all Research One universities in the United States (N = 89). Academic and firm-level data are matched with patent information extracted from the U.S. Patent and Trademark Office database. To ensure patent comparability across sector samples, the academic database is limited to patents in the biotechnology sector. Suitable patent classes were chosen by limiting the university sample to the subclasses which account for the 90<sup>th</sup> percentile and below of life science firm patenting.<sup>15</sup>

I limit the collaboration network to firms and universities in the Boston region. I do so to provide a natural boundary on the scope of the network so as to maintain a manageable size for which to analyze the data. The Boston region is one of the top three areas of regional biotechnology development in the United States. Boston is unique in the sense that, in conjunction with biotechnology firms, its university activity and the activity of other public research organizations (for example, Dana Farber Cancer Institute and Massachusetts Eye and Ear) play a significant role in driving regional biotechnology innovation (Owen-Smith and Powell 2004;

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<sup>14</sup> There is a noticeable absence of large multi-divisional corporations, such as pharmaceutical companies, in all major biotechnology regions in the US, including Boston, during this time period (Owen-Smith and Powell 2004. Their lack of presence in the Boston network makes it difficult to ascertain the structure of inventor collaborations in large, hierarchically oriented, firms such as these. Novartis and Pfizer, however, both recently moved their R&D facilities into the Boston area since 2002, no doubt attempting to anticipate benefits from a closer location to such a dominant biotech regional economy. My dissertation work includes these organizations to enable a more fine-grained observation of the differing organizational contexts of industrial work settings.

<sup>15</sup> It happens to be the case that these same classes hold the majority of the top patenting classes in university patents.

Porter, Bunker Whittington, and Powell, 2005). For this reason it is useful to analyze the Boston area because of the jointly significant roles that universities and private firms play.<sup>16</sup>

Multiple inventions by the same person also involve the confirmation of similar names. Inventions are considered to be from the same person when two inventors match in first, middle, and last name (or part thereof, in the case of missing middle or first names). Importantly, however, two names are only considered a match if they have similar first, middle and last names *and* a similar city and state, assignee name, or the same primary *and* secondary technology class.

In addition, inventor gender is coded through the assistance of an algorithm that determines gender based on first name comparisons with a list of names (broken out by gender) from the 90<sup>th</sup> percentile and below of the 1990 U. S. Census.<sup>17</sup> This list contains not only 90% of the most common names in 1990, but the cumulative percentage of the U. S. population with each name. In the case where a name appears on both the male and the female list, the cumulative percent for the name in each gender is compared. Names in dispute that are above the 70<sup>th</sup> percentile are considered rare, and gender is assigned to the opposite sex.<sup>18</sup> Decisions are not made about androgynous names (that is, names found on both a male and female list) where a cumulative percentage is not given or jointly rare. There is a tendency in the name-matching algorithm to find matches for a greater percentage of scientists with a typical “American” name, as many foreign-based names are not present in the 90<sup>th</sup> percentile of the U.S. population. Much of the ~17% missing data lies in names of Indian and Chinese descent, both of which are difficult to code for gender.<sup>19</sup> The missing data is still included (labeled “Gender Unknown”) in the network to maintain its integrity.

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<sup>16</sup> In addition to firm and university inventors, I include collaboration networks of those in public research institutions. Although not the focus of this paper, the significant role such networks play in the Boston region suggests a more accurate picture of the joint firm-university network is achieved with their inclusion.

<sup>17</sup> See Bunker Whittington (dissertation) for a detailed description of the name-matching algorithm.

<sup>18</sup> When possible, names not on the 1990 census are coded using secondary name data, found in books and websites with downloadable lists of ethnic and foreign names.

<sup>19</sup> In their complexity, Indian names are hard to compile into lists of *common* names. Chinese names tend to be androgynous when spelled in English, where gender is typically relayed in tone and written character in the Chinese

In the final sample there are 49 firms, 4 universities (Harvard, Tufts and Boston University, and MIT), and 13 public research organizations (other than the universities) in the Boston area between 1976 and 1998. There are 1115 inventors who have participated in a total of 1375 patents between 1976-1998 in the Boston DBF network, and 1003 inventors who have been granted 792 patents between 1976 and 1998 in the Boston university network. The Boston firm and university networks are comprised of 25% (N = 235) and 18% women (N = 153), respectively.

### ***The Network***

The data for this analysis represent two-mode affiliation data, where the inventors are the actors and each patent is the event. In this way, a connection between actors is assumed strictly by their collaboration activity. The affiliation network, when multiplied with its transpose, produces a one-mode actor by actor network. I depend solely on this “one-mode” inventor-inventor network in this paper.

I present network visualizations through the network program Pajek. Pajek produces network images by applying energy-based physical science algorithms that act to minimize node “strain” based on the inventor ties across the network. I create network images using Pajek’s Kamada and Kawai (1989) and Fruchterman and Reingold (1991) energy algorithms.<sup>20</sup> This two-step process is done first to map and spread the structure of the network, and then to optimize that spread according to the constraints inherent in the node relationships.<sup>21</sup>

I first present network graphs of the collaboration structure of all sectors *combined*, and then of the largest components in the academic and industrial sectors separately. The structure of collaborations among scientists in industry and academia exhibits characteristics that embody the

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language. Presumably these missing names contain a similar percentage of men and women to the matched data, although that itself is not knowable.

<sup>20</sup> For more information on the algorithms or their use for visualization, see Owen-Smith et. al. 2002; Powell, et al 2005, and <http://vlado.fmf.uni-lj.si/pub/networks/pajek>.

<sup>21</sup> All networks are optimized to account for the number of patents in an inventors collaboration profile.

sector-level influences discussed above, and as such, visually shows ways in which organizational context may act to influence individual action within employment sectors.

### *Network Visualizations*

Visualizations of the combined network show the relationship between academic and industrial collaboration networks, and their structure within sector. I focus my analysis of the patent collaboration network on the largest, weakly connected component in a network (White and Harary, 2001; Moody and White, 2003). This structure, the ‘main component,’ represents the greatest concentration of co-inventors, and the largest hub of patenting collaboration in the Boston region.<sup>22</sup>

Figure 1 is a visualization of the main component of the co-patenting network across time (1976-1998), with 1298 inventors. Circles represent university inventors, squares are biotechnology firms, and triangles are public research organizations. A select group of 127 individuals have patents assigned across universities, industry, or public research organizations. These inventors are represented with diamonds. Gender is coded by color - black nodes are female inventors, gray nodes are male inventors, and white nodes are scientists of unknown gender.

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Figure 1 about here  
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The central force in Figure 1 is the expansive “pump” of university inventors in the center of the drawing. This cluster represents the laboratory work of Dr. Robert Langer and his students and colleagues from MIT. Spreading out from the Langer cluster in the center are several firm, university, and public research organization components, connected through the cross-sector inventors. Though not the immediate focus of this paper, the combined network shows the

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<sup>22</sup> Visualizations of the main component omit all inventors with no collaboration ties to others, and smaller clusters of collaborators that do not connect to the largest cluster. In this network, there are very few small clusters of collaborators besides the main component.

important role that multivocality plays in linking the two sectors together (Padgett and Ansell 1993, Powell et al 2005). While only 9.8% of the scientists in the component are cross-sector inventors, without them the network breaks into 9 pieces of within-sector only collaboration. Had these 127 inventors not cross patented, the combined network would look vastly unconnected.

That said, the full network is largely comprised of sector-similar activity. Breaking the full network down by sector, we see distinct clusters of activity within academic and industrial life science. In the Boston region, there are 4 main industrial and 3 main academic components (all nodes in a component are connected to each other by at least one reachable path). Figures 2 and 3 display the largest components in both the academic and industrial sectors, respectively. The network of collaborations in each of these components has implications for the structure of science in academic and industrial settings, and the level of gender disparity seen in both. I focus on each in turn.

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Figures 2 and 3 about here  
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### ***Academic Collaboration Networks***

Figure 2 shows the structure of the largest academic component in the Boston university network. This component is a cluster of MIT scientists, with patents from Langer’s laboratory in the center of the largest hub. This network contains 16% female scientists. The structure of academic science resembles that of a bicycle wheel. “Star scientists” are located in the middle of the wheel structure, and collaboration networks extend out from the scientists like spokes. Connections may exist to other “wheel-like” structures of star scientists, in which collaboration networks again surround the one, central scientist in the center. Figure 2 suggests that the structure of academic science reflects the organizational goals of the university. Here, head scientists represent the most central locations, and the domain within which each operates is kept largely separate from other head scientist domains. Networks of collaborations are centered around one



area and only tangentially tied to other networks of collaborations. This may represent ways that academic scientists organize, not only to facilitate large research projects, but also to offset priority-loss and maximize economies of scale. The network drawings provide insight into how informal relationships - cemented through formal patent assignments - are shaped by (and continue to shape) the structure of organizational system.

The right-hand visualization in Figure 2 presents the same academic structure, but organized hierarchically by level of degree centrality. Each level represents a standard deviation above the average degree centrality of the component (represented at the lowest level). This version of the network shows the hierarchical structure of scientists in the academic system. Robert Langer is the top node, and below him are the collaborators that in the network to the left formed the spokes of the Langer wheel. In academic science, star scientists (in this figure there are two) reside at the top with limited paths and connections between individuals. When viewed this way, the network suggests that collaborative action among inventors is closely orchestrated through the actions of a few highly influential individuals.

Figure 2 also lends insight in how supply side demands may be shaped by the system. Consider one's location in the Langer hierarchy. Moving or finding opportunities and other resources beyond the Langer cluster may be a difficult task given the single node collaboration connections from which the Langer cluster is linked to other clusters at MIT. In university settings, scientist's ability to appropriate information and reach potential collaborators is limited structurally by the inherent linkages (or lack of them) between clusters. Whether a scientist knows about his or her resource limitations or is only aware of the difficulty in learning of them beyond his or her place in the system yields similar hindrances. Visualizing how scientists are located in the structure of academic science suggests ways to conceptualize how scientists' decisions and actions may interact with the existing structure of academic science.

### ***Industrial Collaboration Networks***

The structure of industrial science looks quite different from that of academic science. Figure 3 presents visualizations of the largest connected component in the Boston firm network. All of the inventors in this component have patented technology developed from a notable biotechnology firm, Genetics Institute.<sup>23</sup> In comparison with the main academic component, which has 16% female scientists, the industrial component has 32%. In addition, we see a clear lack of “star scientist” activity, where many nodes are connected to one node but not to others, and an increase in nodes that are reachable through many paths. This difference is evident visually, but also through descriptive information on the two networks. Whereas the average path distance of reachable nodes in the academic network is 1.3, the industrial average is 2.0. This difference suggests that the research networks of industrial scientists span a greater distance than those of academic scientists.

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Figure 3 about here  
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Like the academic network, Figure 3 reflects the structure of industrial science, with its associated organizational goals and incentives. Whereas academic scientists are organized around specific labs and top scientists, industrial scientists are organized around research problems. Lacking world-class superstar scientists, research teams operate more collaboratively. Research teams within firms share information, supplies, and human capital with other groups. Across firms, research collaborations with other companies enhance the flow of ideas and resources across many individuals. Thus, we see sector-level organizational goals and incentives reflected in the structure of industrial science.

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<sup>23</sup> Genetics Institute was acquired in 1998 by Wyeth, a large pharmaceutical company, but continues to operate as an independent division.

Figure 3 also presents the same industry component, but organized hierarchically by degree centrality. In comparison with the university network in Figure 2, it is notable that the variance of degree centrality for academic scientists is 6.7, whereas the variance for industry scientists is 3.6. This indicates that industrial scientists have less spread in the distribution of degree centrality than academic scientists. Visually, it is immediately clear that the hierarchy in the industry network is more dispersed as compared with the academic network. Instead of all nodes connected to one or two top scientists, in these firms multiple inventors are connected to many other inventors. Measures of connectedness may be similar across the two sectors, but it is connectedness *to whom* that makes the difference.

Figure 3 suggests that inventive activity in small dedicated biotechnology firms looks rather different than in an academic setting. In biotech firms, the lack of a strong hierarchy and sharp scientific competition speak directly to the nature of the industrial science system, and has implications for how the supply side of sector activity may shape or be shaped by the structure of industrial science. Because the network is more dispersed hierarchically, scientists may have more resources to draw from, and more ability to appropriate new research collaborators. Network mobility seems more fluid in small firm industrial science. Instead of movement being restrained through the one node that connected the Langer cluster to other research areas, scientists within one part of the industrial firm network have many collaborative opportunities available to them to connect with others in the network. In this way, the structure may help to shape the decisions scientists make, and their involvement in dissemination in general.

### ***Network Discussion***

The network visualizations suggest that the structure of scientific collaboration closely follows that of the arrangements of work in the academic and industrial organizational forms. A key difference between academia and dedicated biotechnology firms is how the structure of knowledge production is organized within each. In the former, the university is arranged around

the laboratories of tenured scientists. Collaborators, often graduate students and/or research scientists, are frequently responsible for small pieces of work within the laboratory's focus. The structure of science in this academic setting is such that all research (commercial or otherwise) is tied through the head scientist, and collaborations with others in the lab and across labs with the same focus are often kept to a minimum. Like academic science, in biotech firms there may also be a comparable focus on a specific therapeutic arena. In this setting, however, scientists move from research project to research project within the firm, and are often characterized as "voting with their feet" because of the way they move across and between successful research projects in the organization.<sup>24</sup>

I suggest that the difference between the broadly distributed work of academic science and the more horizontal distribution of knowledge in biotech firms may be important in explaining differences in productivity between male and female scientists within industry and academia. Previous research suggests that women and men create and exist in qualitatively different patterns of interaction within their work setting (Brass 1985; Smith-Lovin and McPherson 1993; Ibarra 1992). Women tend to exist in networks that have more strong relations, and potentially, have access to a fewer number of important bridging, influential ties in their networks. Because industrial settings may be less competitive within firms, or there may be more designated or directed positions of collaboration, women may be better able to access these types of beneficial ties. Additionally, scientists' position at the confluence of reputation and collaborative networks may just not be as important in industrial settings as they are in academic ones, where scientists' networks can matter greatly to help offset loss through priority-based competition. If this is the case, we may see less of an influence of network position and productivity for scientists in industrial jobs, and differences in men's and women's networks are not as likely to matter as much for research output as in the academy. Thus, gender differences in patenting may be amplified in

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<sup>24</sup> For a poignant example of this, see the Harvard Business School Case on "planning the un-plannable" in Amgen, a large, successful biotechnology firm in Los Angeles, California (Nohria and Berkley 1992).

public versus private settings due to variations in a) the differing network positions of men and women, and b) the varying importance of network position on productivity in industry and academia.

My dissertation explores these ideas more fully. This initial work shows key visual differences, but from the network data it is possible to construct standard measures of individual network centrality and overall network centralization, as well as various measures of male and female position characteristics. The dissertation pays particular attention to inventors located in “brokering” positions (Burt 1992). Brokers are nodes that are situated in between two or more groups that lack ties to one other. Those in brokering positions benefit from their position because they may have increased exposure to new and different information, they may be the first to see new opportunities in research, and they can bring together new collaborative ventures with available others, among other things. I explore the extent to which industrial female scientists are more likely to be in brokering positions than academic female scientists. In general, I show the degree to which the structure of academic and industrial science is statistically related to the degree of gender disparity in patenting. I argue that one’s position in the network matters, but in addition, the structure of one’s network may also play a more defining role.

One limitation of the network visualizations is that they include *all* connections among *all* individuals over time, and cannot speak to the stability of the network structure over the years. My future work will look at changes in the network structure over time to provide evidence of causality between the impact of structure and the impact of scientists’ decisions. A related and pertinent issue of the network graphs is how the organizational arrangements of large, broadly distributed corporations (such as pharmaceutical firms) are similar or dissimilar from that of dedicated biotechnology firms, as well as the academic life science setting. For reasons documented more fully in the dissertation, I suggest large corporations may have a similar structure and dynamic to that of university science. Including the activities of scientists in large pharmaceutical firms will

help to illuminate how this structure may also contribute to greater gender disparities in commercial involvement.

#### 4. Conclusion

The log linear models confirm that sector-level differences in gender disparities exist in the life sciences, while also showing this discipline to be relatively unique in this regard. Viewed in conjunction with previous research that shows the effects of industrial life sciences are driven by smaller, dedicated biotechnology firms (Bunker Whittington and Smith-Doerr 2006), these results suggest that sector-level differences may be due largely to features contained within the differing organizational forms of academic versus small dedicated biotechnology settings. The network visualizations suggest ways in which the structure of science varies across these diverse work settings, and illustrate how male and female scientists' commercial involvement may be related to their positions within this structure.

An important caveat of this research is that it deals with sector differences in “involvement” in dissemination activities, rather than “productivity” (i.e. amount of patents or articles) per se. Academic gender disparities in the life sciences are greater when looking at involvement in commercial behavior, to any degree, but in contrast, analyses using a *count* of patents showed similar gender disparities across employment sectors.<sup>25</sup> Hence, differences between the academic and industrial sectors appear to stem largely from unequal opportunities to engage in such behavior, rather than the amount of productivity once involved.

Because academics are typically free to choose their research topics, gender differences in involvement within the university may suggest that fewer women have exposure to the commercial process, or alternatively, foster a research focus that lends itself to becoming commercially involved. A more structural explanation for this may be that women lack institutional support for

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<sup>25</sup> In these two-stage sample selection models predicting first, involvement in commercial activity, and second, the amount invented, women continue to patent less than their male counterparts. Unlike commercial involvement (to any degree), these models show no differences across employment sectors in gender disparities when looking at the number of patents granted to men and women in academic versus industrial science. (Bunker Whittington and Smith-Doerr 2006).

patenting. Perhaps universities fail to support initial commercialization for female scientists, but once involved, women patent at rates similarly to men. Without further research, it is hard to speak to female scientists' motivations and interests in commercial work. My future work explores these ideas more fully with qualitative data from scientists working across academic and industrial settings. At the very least this research highlights the importance of conceptualizing dissemination as a separate, two-part process – involvement, to any degree, and then amount, once involved.

Of final interest is how male and female dissemination compares across disciplines. The log linear models clearly show something unique about the life sciences regarding sector-level differences, as these effects do not occur in the physical sciences and engineering. Viewed in conjunction with additional research showing the strong role that biotechnology firms play in the relative commercial gender equality of industry, the implication is that something distinctive is occurring in the structure of or group of workers in these work settings. Although commercial work is becoming more common in all disciplines, the life sciences exhibit a higher proclivity to commercialize than other sciences. At their core, biotechnology firms have a financial bottom line to meet and, in the case of scientific work, they also aim to maximize their accumulation of proprietary information. Hence, these firms are also likely to attract scientists with knowledge and expectations of patenting. Conversely, for many of the reasons mentioned above, participation in an activity that has historically been seen as “supplementary” (and even controversial) may be more likely to lag among scientists in the academy. In the physical sciences and engineering, female scientists are a rarity, and work settings may not be organized to maximize commercial activity as efficiently as in life science firms. Thus, female workers may be equally less likely to patent in both universities and industrial firms. The combination of these two factors may produce the greatest differences in the life sciences across the two sectors. I present these cases in hopes of stimulating future research on gender dynamics in physical science and engineering firms.

In conclusion, at the heart of this research is the goal of gaining a better understanding of how work environments and changes in the context of science may make a difference on the

known disparities between men and women scientists. With academic participation in both basic science and commercial endeavors on the rise, the fact that female scientists in the academy may lag behind their male counterparts, for whatever reason, and are more comparable to their industrial counterparts has significant implications for the future labor market choices of female scientists. As commercialization becomes more common and has more repercussions for academic scientists, these trends have considerable implications not only for the scientific labor market, but the wider pursuit of knowledge as well.



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Table 1. Percent of Women and Men Involved in Dissemination Activity, by Employment Sector (1990-1995).

Dissemination Activity	Academia				Industry				Total			
	Percent Male	Percent Female	Percent Total	Prop. Female	Percent Male	Percent Female	Percent Total	Prop. Female	Percent Male	Percent Female	Percent Total	Prop. Female
Neither Publish nor Patent	4.1	3.8	4.0	0.19	21.3	18.6	21.0	.11	12.7	9.3	12.2	.13
Publish Only	80.2	88.5	82.0	0.23	38.5	50.4	39.9	.15	60.3	75.4	62.8	.20
Patent Only	0.6	0.2	0.5	0.09	11.5	6.5	10.9	.07	5.6	2.2	5.1	.07
Both Publish and Patent	15.1	7.5	13.5	0.12	28.7	24.5	28.2	.10	21.3	13.1	20.0	.11
Total (all forms)	---	---	---	0.21	---	---	---	.12	---	---	---	.17

SOURCE: National Science Foundation/Division of Science Resources Statistics. Scientists and Engineers Statistical Data System (SESTAT), 1995.

N(unweighted) = 10,144  
 N(weighted) = 157,372

Note: This table reflects statistics from the weighted sample.

Table 2. Log-Linear Models of Scientific Dissemination, Gender, Discipline, and Employment Sector, 1990-1995.

Model Description	Terms in the model	Residual df	Goodness of fit	LR p-value	BIC
1. Constant Only	1	71	22686.8	0.0	22031.8
2. Model 1 + direct effects	9	63	4903.2	0.0	4322.1
3. Model 2 + Pat/Pub Activity * Employment Sector + Pat/Pub Activity * Scientific Discipline + Scientific Discipline * Employment Sector + Pat/Pub Activity * Employment Sector * Scientific Discipline	37	35	1085.4	0.0	762.5
4. Model 3 + Gender * Pat/Pub Activity	40	32	891.3	0.0	596.1
5. Model 4 + Gender * Scientific Discipline * Employment Sector	48	24	43.7	0.001	-177.7
6. Model 5 + Gender * Pat/Pub Activity * Scientific Discipline + Gender * Pat/Pub Activity * Employment Sector	60	12	24.8	0.02	-85.9
7. Model 6 + Gender * Pat/Pub Activity * Scientific Discipline * Employment Sector (Saturated Model)	72	0	N/A	N/A	N/A

Table 3. Odds Ratios for Male and Female Scientists by Employment Sector, Holding Discipline Constant.

	Life Sciences		Engineering		Physical Sciences	
	Academia	Industry	Academia	Industry	Academia	Industry
<b><i>Publishing Only<sup>a</sup></i></b>						
Male	3.705	1.430	2.272	0.066	2.584	0.777
Female	3.122	1.679	5.752	0.038	3.139	0.626
Relative Log Odds (M-F)	0.583***	-0.249	-3.480	0.028	-0.555	0.151
Relative Odds	1.791***	0.780	0.030	1.028	0.574	1.160
<b><i>Patenting Only<sup>a</sup></i></b>						
Male	-1.187	-0.950	-3.275	-2.112	-3.275	-0.253
Female	-2.809	-1.110	-1.349	-2.917	-3.575	-0.796
Relative Log Odds (M-F)	1.622**	0.160	0.146	0.805**	0.300	0.543
Relative Odds	5.063**	1.174	0.146	2.237**	1.350	1.721
<b><i>Both Publishing and Patenting</i></b>						
Male	1.926	0.730	1.181	-0.196	0.705	0.741
Female	0.647	0.784	3.925	-0.533	0.388	0.141
Relative Log Odds (M-F)	1.279***	-0.054	-2.744	0.336	0.317	0.600**
Relative Odds	3.593***	0.950	0.060	1.399	1.370	1.820**

Notes:

<sup>a</sup> The odds ratios for *Publishing Only*, *Patenting Only*, and *Both Publishing and Patenting* have *Neither Publishing nor Patenting* as a comparison group.

\* p < 0.1 \*\* p < 0.05 \*\*\* p < 0.01 (two-tailed)

Figure 1. Boston Patent Co-Inventor Network, Main Component (1976-1998)

<u>Node Color</u>	
Gray:	Male (75.3%)
Black:	Female (16.0%)
White:	Gender Unknown (8.8%)
<u>Percent Female:</u>	
Industry:	22.5%
Academia:	11.2%
PRO:	16.8%
<u>Node Shape</u>	
Square:	DBF (21.2%)
Circle:	University (49.3%)
Triangle:	PRO (19.7%)
Diamond:	Cross-sector (9.8%)

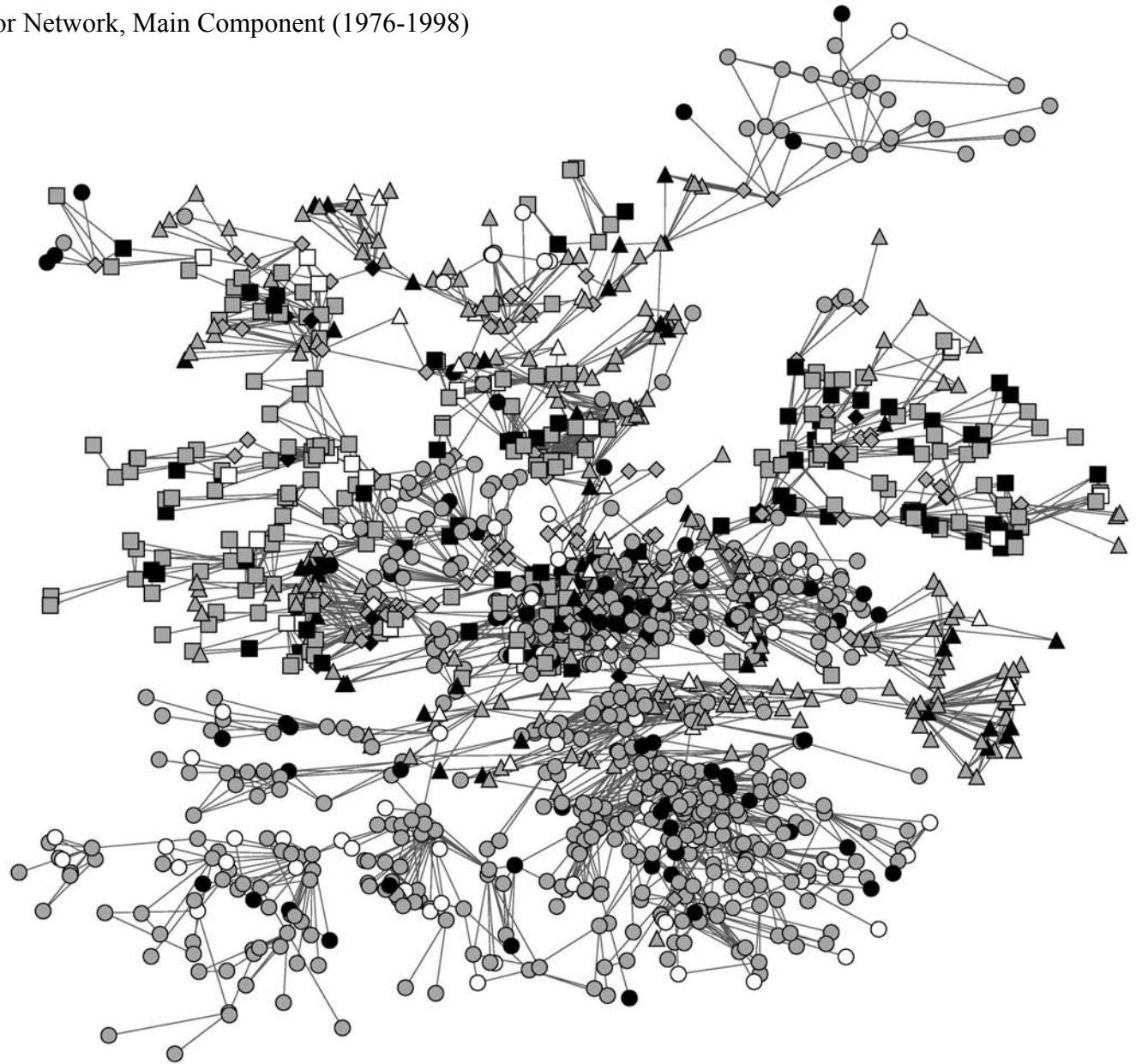
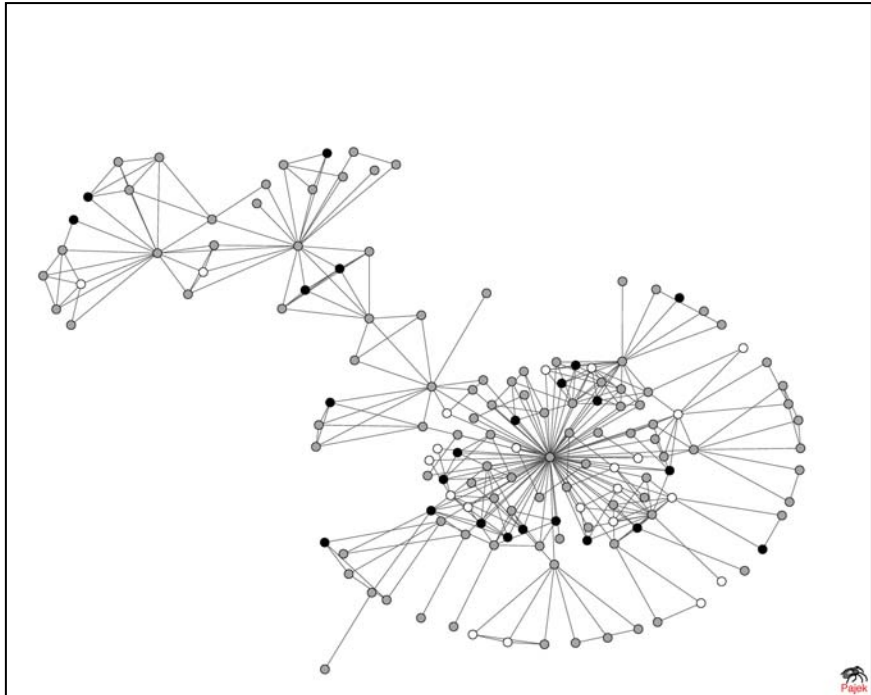


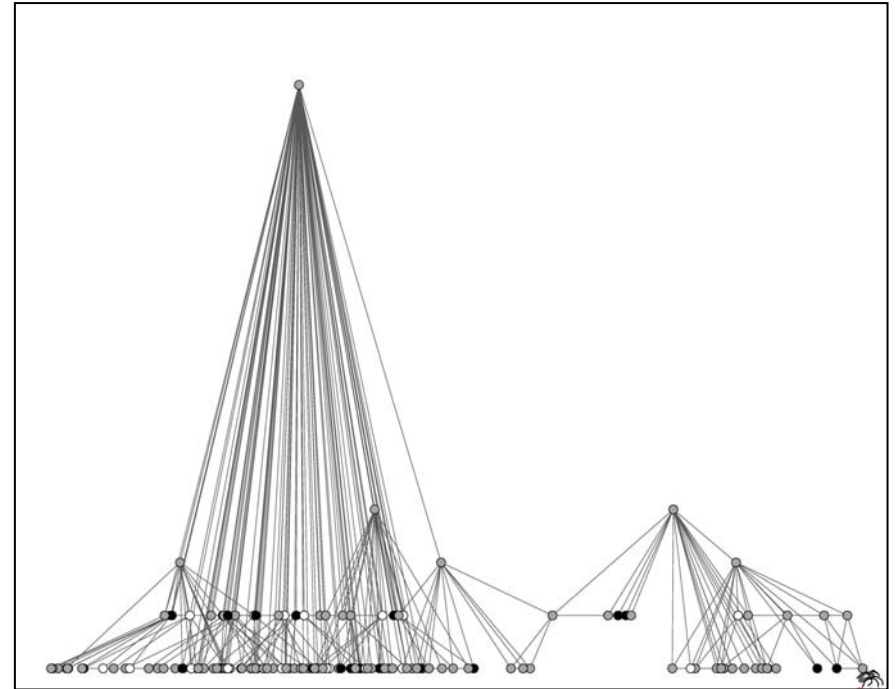


Figure 2. Largest Collaboration Component, Boston Universities (1976-1998)



Network Graph

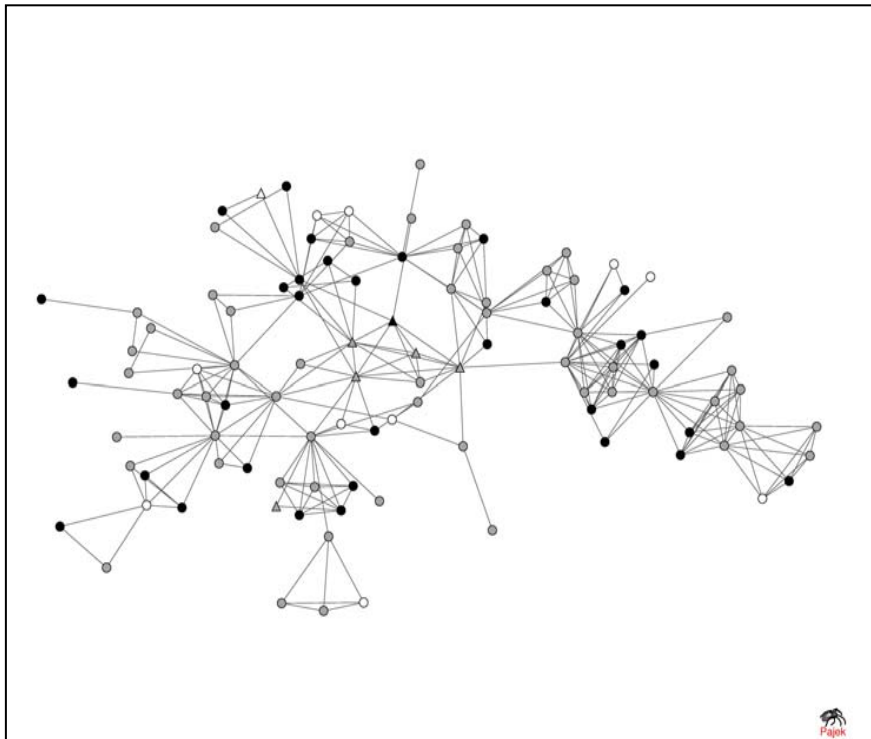
Male Inventor (Gray nodes): 69%  
Female Inventor (Black): 16  
Unknown Gender (White): 15



Degree Distribution

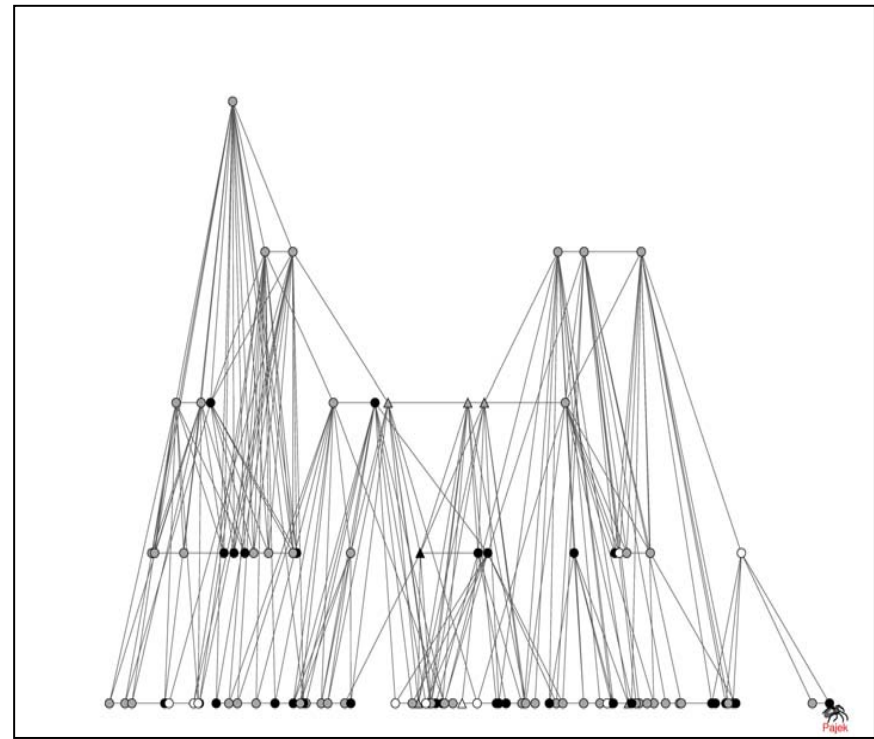
Bottom Level, Average: 5.6  
Subsequent Levels, Std. Dev.: 6.7  
Overall Centralization: 0.9

Figure 3. Largest Collaboration Component, Boston Firms (1976-1998)



Network Graph

Male Inventor (Gray nodes): 57%  
Female Inventor (Black): 32  
Unknown Gender (White): 11



Degree Distribution

Bottom Level, Average: 5.4  
Subsequent Levels, Std. Dev.: 3.7  
Overall Centralization: 0.3