How Do Career Strategies, Gender, and Work Environment Affect Faculty Productivity Levels in University-Based Science Centers?[1]

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Abstract

Recent studies have shown that in many science and engineering fields, almost 40% of faculty are affiliated with university-based research centers (Corley & Gaughan, 2005). As major science funding organizations continue to increase annual levels of funding for interdisciplinary science centers, it is likely that this number will increase significantly over the next decade. Moreover, some scholars have argued that the rise of university-based science centers has already led to the development of a new institutional form for the execution of university-based research (Bozeman & Boardman, 2004). Yet, interestingly few researchers have studied the impacts of this new institutional form on the productivity of individual researchers.

The purpose of this article is to begin to address how individual career strategies and perceptions of scientific work environments within university-based science centers relate to the productivity of academic scientists who participate in these centers. In particular, this article investigates the relationships between productivity, individual career strategies, and perceptions of scientific work environment across gender. The results of the study demonstrate that university-based science centers might serve as an equalizing mechanism for male and female productivity levels. Yet, women scientists affiliated with these centers are significantly more likely to feel discriminated against—and they are less likely to embrace the most promising career strategy for the current structure of these centers.

Introduction

As major science funding organizations (such as the National Science Foundation [NSF], the National Institutes of Health, and the Department of Energy) continue to increase financial support for cutting edge science and engineering research through interdisciplinary center mechanisms, social science and policy scholars are increasingly interested in how those centers impact the productivity levels of individual researchers. When studying individual career trajectories for male and female faculty, we can no longer focus only on how individuals perform in the environments of traditional disciplinary departments. Recent studies show that in some science and engineering fields, around 40% of faculty are affiliated with university-based research centers (Corley & Gaughan, 2005). In fact, some scholars have argued that the rise of university-based science centers has led to the development of a new institutional form for the execution of university-based research (Bozeman & Boardman, 2004).

The development of this new institutional form for the conduct of science research means that directors of university-based science centers face hurdles that are quite different from the challenges that traditional department chairs must address (Bozeman & Boardman, 2003). In particular, university-based science centers usually bring together interdisciplinary groups of scholars who have diverse disciplinary incentives for promotion and tenure, a range of incentives for acquiring grant money, a mixture of collaboration incentives, and varying departmental

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teaching expectations. Given this amalgam of professional goals and incentives, directors of university-based science centers face increasingly complex challenges as they try to provide a supportive work environment for a diverse group of affiliated faculty members. Even though there is some early recognition that university-based science centers represent a new institutional form for the performance of scientific research (Bozeman & Boardman, 2004), few studies have focused on exploring the effects of the new institutional form on individual career trajectories and productivity rates. The purpose of this article is to begin addressing this question by exploring how individual career strategies and perceptions of scientific work environments within university-based science centers relate to the productivity of academic scientists who participate in federally funded science centers. In particular, this article will delve into the relationships between productivity, individual career strategies, and perceptions of scientific work environment across gender.

The large majority of studies on the success of university-based science centers focus on organization-level units of analysis, rather than impacts of the centers on individual researchers. However, a few researchers have explored how individuals succeed within these centers. For example, Hetzner, Gidley, and Gray (1989) briefly mention the issue of individual faculty participation in industry–university cooperative research centers (IUCRCs). They report, very generally, that faculty members expect research funding to flow from their participation in IUCRCs—especially because of the excessive proposal writing requirements placed on them as members of these centers. Additionally, Hetzner and colleagues state that some faculty report that participation in centers leads to more interactions with other faculty, more support for student research, greater access to equipment, and improved consulting and research opportunities. Hetzner and colleagues conclude, therefore, that these centers appear to be supporting some of the traditional core of faculty activities.

Before describing the data collection and data analysis for this study, I will provide an overview of the results of previous studies that have explored gender differences in the productivity rates of academic scientists. After discussing the existing literature on scientific productivity across gender, I will present a description of the data collection for this study. Then, findings on the relationship between individual career strategies, perceptions of science center work environment, scholarly productivity, and gender will be explored. Lastly, I will discuss the implications of this research for United States science policy (in general) and the management of university-based science centers (in particular).

Scientific Productivity and Gender

Over the past several decades, social science and policy scholars have explored productivity levels across gender, with many demonstrating that women faculty members publish less, on average, than their male colleagues do (Bentley & Adamson, 2003; Broder, 1993; Cole & Singer, 1991; Mathtech, 1999; Sonnert, 1995). This gender gap in publication records has been correlated to a variety of variables, including timing of the first publication (Clemente, 1973; Reskin, 1977) and departmental reputation (Allison & Long, 1990; Long, 1978). For example, Keith, Layne, Babchuk, & Johnson (2002) studied how publication histories and organizational context differentially affect the research productivity of male and female sociologists. They found that differences in research productivity for male and female academics emerge gradually over time, with males and females not differing significantly in their publication records as graduate students. Yet they did find that males published significantly more than females within two years after completion of the doctorate, which is a critical career phase for both genders.

Some scholars have argued that female academics publish less than male scientists because they do not advance through the academic ranks as quickly as men do. For example, Weiss and Lillard (1982) reported that academic women wait twice as long as men to be promoted. In a related argument, many scholars have argued that women do not advance through the academic ranks quickly because they are more likely to enter the academic job ladder with positions that have less potential for future promotion and tenure (Bentley & Adamson, 2003; Brennan, 1996; Carnegie Foundation for the Advancement of Teaching, 1990). Barbezat (1992) found that women are more likely to be employed in academic jobs that stress teaching more than research; however, after controlling for stated job preferences, gender did not have an effect on actual employment placement. In the Barbezat (1992) study, women placed a higher value than men on student quality, teaching load, collegiality and interaction within department, and female representation on the faculty. Conversely, men placed a higher value on salary, benefits, and research time.

Separate studies by the Carnegie Foundation (1990), Kahn (1993), and Long (2001) found that women are less likely than men to hold a tenure-track or tenured position. Miller-Loessi and Henderson (1997) found that academic women are more likely than academic men to be in lower rank positions at universities, while Bentley and Adamson (2003) reported that women scientists and engineers tend to be underrepresented in senior academic ranks. Everett and colleagues (1996) also reported that academic female chemists were less likely to make it to the full professor level than men (with 20% of women at full professor compared to 59% of men).

Fox (2001) further explored this issue when she explained that the highest career attainments for academic women scientists generally elude them. Using the definition of science that is comprised by the eight classifications of the National Science Foundation and the National Research Council (physical, mathematical, computer, environmental, life, engineering, psychological, and social), Fox points out that the proportion of women at the rank of full professor are meager in all areas except psychological science (Fox, 2001). In 1995 within the fields of physical, mathematical, engineering, and environmental sciences, women held 6% or fewer of the full professor positions (Fox, 2001). Rossiter (1982, 1995) has argued that even though women have been participants in science fields for quite some time, they have not been in valued, highly rewarded, or even visible roles. Findings such as these might partially explain the results of studies such as those conducted by Stack (2002), Nakhaie (2002), and Ginther and Hayes (1999), who all found that publication rates are more strongly correlated with academic rank than with gender. Perhaps women scientists are "stuck" in lower level academic positions and this affects their publication rates.

Many have also hypothesized that the gender difference in publication rates can be attributed to the fact that, on average, women are more likely than men to carry the majority of household chores and child rearing. Suitor and colleagues (2001) collected data from 673 faculty members at one research university to explore the relationship between the division of household labor and scholarly productivity for male and female academics. They found that women professors carry more of the household labor than male professors do, especially when they are married and there are children in the home. Yet, this discrepancy in the division of labor for male and female academics did not translate into a reduced level of research productivity for the female academics in all cases. Only for one group, tenure-track female academics with children at home, did the increased household labor translate into reduced productivity for women scholars.

Shauman and Xie (1996) hypothesized that female scientists are more likely to have reduced career mobility than male scientists because they are more likely to be in two-career marriages. They found that family constraints on women scientists' careers are relatively weak when they do not have children, although the constraints become significant when women scientists do have children.

Even though many studies have shown that women scientists often lag behind male scientists in research productivity, some studies show that the gender gap for scientists and engineers[2] seems to be decreasing (Stack, 2002), particularly in the "softer" science fields. Stack (2002) focused his analysis on the research productivity of 89 faculty members in criminal justice departments. He found that gender was not significantly associated with either the number of articles or the impact of the scholarly work for the criminal justice scholars in his sample. Instead, Stack discovered that the leading predictors of scholarly productivity were faculty rank and year of doctoral degree. Nakhaie (2002) analyzed data from a Canadian national survey of professors to explore the reasons why female scientists, on average, publish less than male scientists. Nakhaie found that there were differences in the number of publications reported by male and female academic scientists, with men publishing significantly more than women. However, much of the difference between the publication rates of the genders was due to differences in rank, years since PhD, discipline, type of university, and time set aside for research.

Ginther and Hayes (1999) explored the relationship between promotion to tenure and the salary gap between men and women in humanities fields. They hypothesized that if gender differences in faculty salaries or promotion existed after controlling for productivity, then the differences would suggest that women were receiving lower salaries and fewer promotions because they were women, not because they were less productive. Ginther and Hayes found that observed gender differences in salary were largely explained by academic rank; however, they did find that there were gender differences in promotion to tenure after they controlled for productivity, demographics, and discipline.

Clearly, many scholars have tried to determine whether there are true gender differences in the publication rates of scientists and engineers—and how these differences vary across diverse disciplines. Even though there seems to be no one "right" answer, most studies have shown that women scientists publish less than male scientists—and that those differences are aggravated (if not totally caused by) an assorted set of variables, such as familial obligations, academic rank, time of first publication, and type of university, among others. The research presented in this article explores how (1) perceptions of scientific work environment within federally funded science centers and (2) individual career strategies impact levels of scientific productivity across gender. Before discussing the results of the study presented here, and how productivity varied in this study, the details of the data collection process will be briefly presented.

Data

The concept of scientific productivity has been measured in many ways, but the most common method of measuring scientific productivity has been by counting the number of publications that a researcher publishes. While number of publications is one measure of research productivity—and the measure used in this article—it is not the only measure. The number of citations that an article receives (or the impact of the article) is another way that scholars have operationalized the concept of scientific productivity. Some researchers have defined scientific productivity as an individual's level of external grant funding (Canon, Gabel, & Patton, 2002; Farber, 1977; Raymond, Sesnowitz, & Williams, 1988). Even though there are specific advantages and disadvantages to measuring scientific productivity via article impact factors and grant activity, in the results presented here, productivity is measured by the number of scholarly publications published.

The data used for this study come from two combined sources: scientists' curriculum vitae (CV) and a mailed questionnaire. For the CV data collection, the target population was scientific researchers working in multidisciplinary work groups, particularly in centers funded by the NSF. Therefore, the data are not representative of all university scientists because, among other reasons, the participants are affiliated with centers and the centers tend to be more multidisciplinary, somewhat more applied in orientation, and to have more industry linkages.

In 2000 and 2001, the CV data were collected for 1,041 PhD-level scientists who were not in postdoctoral positions and not working on dissertations. To obtain CVs for these 1,041 scientists, we contacted 13 NSF centers to obtain a list of their scientists and engineers. These centers were chosen for one of two reasons: either because they had been contacted earlier through intensive on-site interviews or the NSF program manager requested that they be included in the study. Therefore, the 13 centers do not represent a random sample of NSF centers because, among other factors, they are biased in favor of centers that have been in existence for at least three years. Initially, all members from the faculty list at these 13 NSF centers were chosen as potential respondents in this study. Therefore, email messages requesting CVs were sent to 3,799 people in the first email wave. Follow up emails were sent twice unless there was a response. After all follow-up emails, the final number of received CVs was 1,106 (a response rate of 29%). The final CV database contained more than 3,000 variables of demographic data, degree data, job data, publication data, patent data, professional affiliation data, and grant award data.

After collecting curriculum vitae data, those individuals were then included in our Survey of Careers of Scientists and Engineers that was conducted from October

2001 to March 2002. A mailed questionnaire was sent to the 997 university faculty members, a portion from the original CV database that included all names in the database except those who provided only partial data, were not university faculty, were graduate students, or were retired. After two mailings 451 questionnaires were received, for a response rate of 45%. The questionnaire included questions about research collaboration, grants and contracts, job selection, career strategies, perceptions of work environment, and demographic information. The data that were used for this study are a combination of the CV data and questionnaire data for the 451 scientists who participated in both phases of the study.

The respondents included 62% tenured faculty, 87% males, and 13% females. Sixty-three percent of the males in the sample were tenured while 52% of the females were tenured. Additionally, 68% of the respondents were native born United States citizens, 14% were naturalized United States citizens, 13% had a permanent United States visa, and 4% had a temporary United States visa.

The scientists in the sample came from a variety of disciplinary backgrounds, including biological sciences, other natural sciences, chemistry, physics, computer science, chemical engineering, civil engineering, electrical engineering, mechanical engineering, other engineering, and social sciences. Table 1 presents the percentage of male and female scientists in the sample within each disciplinary field. The fields with the largest percentage of male scientists were biological/life sciences, other natural sciences (which represents all natural sciences except biological/life sciences), and electrical engineering. The top two fields for the women scientists in the sample were also biological/life sciences and other natural sciences; however the third most popular field for the female scientists was chemical engineering. There were two fields in which there were significantly more female scientists than male scientists: biological/life sciences and social sciences. Computer science was the one field that had significantly more male scientists than female scientists.

Hypothesis and Findings

Measuring Productivity: Publication Rates

A plethora of research has consistently reported that male scientists publish more than female scientists (Allison & Long, 1990; Clemente, 1973; Cole, 1979; Ginther

Table 1. Descriptive Statistics for Disciplinary Field

Discipline	Percentage of Males in Discipline	Percentage of Females in Discipline
Biological and Life Sciences	13.6	25.9
Other Natural Sciences	12.8	13.8
Chemistry	10.7	8.6
Physics	10.5	5.2
Computer Science	6.1	1.7
Chemical Engineering	10.0	10.3
Civil Engineering	3.8	6.9
Electrical Engineering	11.8	6.9
Mechanical Engineering	6.1	3.5
Other Engineering	10.5	5.2
Social Sciences	1.8	8.6

& Hayes, 1999; Keith et al., 2002; Long, 1978; Nakhaie, 2002; Reskin, 1977; Rodgers & Rodgers, 1999). Therefore, we hypothesized that male scientists in this sample of center-affiliated faculty would publish more than the female scientists. As expected, the male scientists in this sample published more. The average total number of publications was 74.04 for male scientists and 35.7 for female scientists. These average values were biased, however, because the male scientists in the sample tended to be older than the female scientists, and, therefore, were more experienced and well published. In our sample there were 368 men and 58 women who reported both gender and age. Of these respondents, the average age in 1996 for the male scientists was 42.9 and the average age for the female scientists was 37.4, meaning that, on average, the male scientists were about 5.5 years older than the female scientists in the sample.

To take the age differential into account, the annual average number of publications since obtaining a doctoral degree was computed for both groups. When looking only at annual average number of publications since doctoral degree, the men in the sample still published significantly more than the women, with men publishing an average of 3.87 publications per year and women publishing an average of 2.82 publications per year. These results include a count of all types of publications (including reports and other publications that were not peer-reviewed). Table 2 presents similar results for only articles, books, and book chapters (all of which are more likely to be peer-reviewed). When articles, books, and book chapters are counted as the only publications, the annual average publication rate since doctoral degree was 3.47 for the male scientists, which was again significantly higher than the annual average of 2.56 for the female scientists.

Past studies on collaboration have shown that although female scientists are just as likely to collaborate as male scientists, they tend to have significantly fewer collaborators (Cole & Zuckerman, 1984). Therefore, our second hypothesis was that female scientists would have fewer collaborators than male scientists. Even though men published more articles per year than the women did, about 88% of the total number of publications for both groups were coauthored, meaning that the female scientists were just as likely as the male scientists to coauthor a publication. Yet, on the questionnaire, women reported slightly fewer numbers of total collaborators (12.02 on average) than the men did (14.04 on average).[3]

Since the reporting of number of collaborators on the questionnaire was not based on coauthorship, but rather was based on the respondent's perception of whether or not someone was a collaborator, there are two possible explanations for this discrepancy between the percentage of coauthored publications and the total

Table 2. T-test for Productivity by Gender

Productivity Measure	Gender	N	Mean	T Value
Annual average publications (all publications) since doctoral degree	Males and Females	437	3.74	−2.812*
	Males Only	382	3.87	
	Females Only	55	2.82	
Annual average publications (articles, books, book chapters only) since doctoral degree	Males and Females	428	3.35	−2.009*
	Males Only	373	3.47	
	Females Only	55	2.56	

*Significant at the 0.05 level.

number of collaborators. Either the women scientists were less likely to count other scholars as collaborators than the men were (and therefore interpreted the collaboration definition differently) or, more likely, the women collaborate just as often as the men do, but with fewer people. The women scientists, on average, collaborated with 8.2 male scientists, while the male scientists collaborated with 10.5 of their male colleagues, on average. The average percent of collaborators who were females was 34.2% for the female respondents and 26.0% for the male respondents. Therefore, the female scientists were more likely than the male scientists to collaborate with female colleagues.

To further explore the relationship between gender and number of publications, an OLS regression analysis was run, controlling for disciplinary field, marital status, number of children, and year since highest degree. For this analysis, the dependent variable was the total number of publications and the independent variables were disciplinary field (which was operationalized as 11 dummy variables—one for each discipline), year of highest degree, marital status, and number of children. The results, which are presented in Table 3, show that gender was not significantly related to the total number of publications when controlling for discipline, marital status, number of children, and years since highest degree. The ANOVA for this model yielded an F value of 17.06 ($p < 0.0001$). Based on the adjusted R square value for the model, the model explained 35.6% of the variation in the number of publications. These results are similar to those found by Nakhaie (2002), who established that much of the difference between publication rates for males and females was accounted for by differences in rank, years since PhD, discipline, type of university, and time set aside for research.

It is interesting that gender was not a good predictor of productivity in this regression, even though three other variables were good predictors. Not surprisingly, the year of highest degree was a good predictor for the number of publications—scientists tend to accumulate more publications as they progress through

Table 3. OLS Regression Analysis Dependent Variable: Number of Publications (Articles, Books and Book Chapters Only)[1,2]

	Unstandardized Coefficients			
Independent Variables[3]	B	Std. Error	Beta	T Value
Constant	7,890.06	651.55		12.11**
Gender[4]	7.13	9.90	0.03	0.72
Marital Status[5]	8.35	11.98	0.03	0.70
Number of Children	–0.42	3.14	–0.01	–0.14
Year of Highest Degree	–3.96	0.33	–0.55	–12.11**
Chemistry	42.91	12.21	0.17	3.51**
Other Natural Sciences	22.67	11.95	0.10	1.90*

*Significant at the 0.10 level.
**Significant at the 0.05 level.
[1]ANOVA: F value = 17.060 ($p < 0.0001$)
[2]Adjusted R Square = 0.356
[3]Additional independent variables include the following insignificant dummy variables for degree fields (dummy variables significant at 0.10 level for disciplines are shown in the table): Biological and Life Sciences, Computer Science, Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, Other Engineering, Physics, and Social Sciences.
[4]Male = 1; Female = 0
[5]Are you currently Married or Living with a Domestic Partner? Yes = 1; No = 0

their careers. The other significant coefficients were for two disciplinary dummy variables: chemistry and other natural sciences. When controlling for gender, marital status, number of children, and year of highest degree, scientists in the chemistry field had about 43 more publications than scientists in the other fields. Similarly, when controlling for the same variables, scientists in "other natural sciences" (meaning other natural sciences besides biological/life sciences) had about 23 more total publications than scientists in the other fields.

Career Plans and Strategies

Although fully capturing the differences between career goals of male and female scientists would be extremely difficult, I expected to get some sense of whether general career goals varied across the genders using this data set. In the questionnaire, scientists were asked to respond to the following Likert-type statements (1 = strongly disagree, 2 = disagree somewhat, 3 = agree somewhat, 4 = strongly agree) that focused on their career plans and strategies.

- My chief goal is to obtain a position in the best research institution possible.
- At some point I would be interested in a position in industry.
- I hope to pursue an administrative position in a university.
- I would be very interested in starting a new company.
- I would be content continuing in a position like my current one for the remainder of my career.
- I am seriously considering leaving research altogether.
- I would consider a job in a government laboratory.

In addition, the respondents were asked to report their past and current experience with administrative positions by answering the following two statements with "yes" or "no."

- I have had an administrative position in the past but do not now.
- I have an administrative position now.

Table 4 presents the results of t-tests for male and female scientists for these nine statements. Male scientists were significantly more likely to have had an administration position in the past, but not now. Female scientists were significantly more likely to consider a job in a government laboratory and less likely to state that their chief goal was to obtain a position in the best research institution. Also, female scientists were significantly less interested in starting a new company.

To construct theoretically motivated measurement models from the data, and to infer possible career strategies from aggregations of individual variables, I factor analyzed the responses to the above nine statements. The factor analysis was completed using principal components analysis with a varimax rotation, imposing an

Table 4. T-test for Career Plan Variables

Career Plan Variables[a]	Mean for Males	Mean for Females	T Value
My chief goal is to obtain a position in the best research institution possible.	2.92	2.65	−1.89*
At some point I would be interested in a position in industry.	2.06	1.91	−1.21
I hope to pursue an administrative position in a university.	1.99	1.98	−0.03
I have had an administrative position in the past but do not now.	0.15	0.07	−2.10**
I have an administrative position now.	0.22	0.14	−1.60
I would be very interested in starting a new company.	2.22	1.83	−2.89**
I would be content continuing in a position like my current one for the remainder of my career.	3.18	3.05	−1.01
I am seriously considering leaving research altogether.	1.45	1.51	0.56
I would consider a job in a government laboratory.	2.14	2.37	1.76*

[a]Reported with a Likert-type Scale, where 1 = strongly disagree, 2 = disagree somewhat, 3 = agree somewhat, 4 = strongly agree.
*Significant at the 0.10 level.
**Significant at the 0.05 level.

Table 5. Principal Components Analysis of Career Plan Variables

	Component[1]		
Variables Describing Career Plans	1	2	3
At some point I would be interested in a position in industry.	0.78		
I would be very interested in starting a new company.	0.42		
I would be content continuing in a position like my current one for the remainder of my career.	−0.63		
I am seriously considering leaving research altogether.	0.53		−0.64
I would consider a job in a government laboratory.	0.63		
I hope to pursue an administrative position in a university.		0.79	
I have had an administrative position in the past, but do not now.		−0.27	
I have an administrative position now.		0.80	
My chief goal is to obtain a position in the best research institution possible.			0.81

Factor 1 = "Disillusioned Scientist"
Factor 2 = "Administrator"
Factor 3 = "Pure Scientist"
[1]Principal Components Analysis; Rotation Method: Varimax

orthogonality constraint. Factor dimensions were extracted to the level of one eigenvalue. The results of this analysis yielded three dimensions—that is, three different career strategies. The results of this factor analysis are presented in Table 5.[4] The three factors accounted for 53.2% of the total variance in the career strategy construct. The "Disillusioned Scientist" was the first career strategy that emerged from the factor analysis. This factor accounted for 22% of the total variance (after rotation). The items with the greatest loadings on this factor generally represented unhappiness with the current career path (e.g., researchers considered leaving research altogether and not content to continue in a position like their current one for the remainder of their career) and plans to pursue a different career plan (e.g., interest in pursuing industry positions, starting a new company, or pursuing a job in a government laboratory).

The "Administrator" is the second career strategy that emerged from the factor analysis. This factor accounted for an additional 17.8% of the total variance. The statements with the greatest loadings on this factor represented a career strategy that focused on being an administrator (e.g., researchers either had an administrative position in the past, had an administrative position at the time of the survey, or hoped to have an administrative position sometime in the future). The third career strategy was the "Pure Scientist," which accounted for an additional 13.4% of the total variance. The statements with the greatest loadings on the "Pure Scientist" dimension represented a career strategy that focused on a strong commitment to doing the best science possible (e.g., the chief goal is to obtain a position in the best research institution possible—also, these researchers are unlikely to consider leaving research altogether).

After completing the factor analysis, I calculated the factor scores (coefficients relating the respondents to the dimensions), which facilitated the use of the career strategy dimensions as independent variables in a regression analysis. Regression analysis was used to determine the level of correlation between career strategy and the number of publications, controlling for the year of the highest degree. The results of this regression analysis are presented in Table 6. When controlling for year of highest degree, the only career strategy type that was a good predictor of the total number of publications was the "Pure Scientist." Researchers with this career strategy published about 5.52 more publications than other researchers (holding year of highest degree constant). Those researchers in the sample who: (1) were not seriously considering leaving research and (2) defined their chief goal as obtaining a position in the best research institution possible fit within the "Pure Scientist" career strategy. Interestingly, the male scientists in this sample were significantly more likely than the female scientists to state that their chief goal was to obtain a position in the best research institution possible (see Table 4 for the t-values in this comparison of means test), although the male and female scientists did not significantly differ in their desire to leave science altogether.

Perceptions of Scientific Work Environment

According to the "difference model," female scientists are less productive than male scientists because the two genders are "different" (Sonnert & Holton, 1995). Many supporters of the difference model argue that female scientists are less productive than male scientists because they have different priorities, which lead to different career strategies. In the previous analysis, the data demonstrated that science center researchers with a "Pure Scientist" career strategy were more likely to

Table 6. OLS Regression Analysis Dependent Variable: Number of Publications (Articles, Books and Book Chapters Only)[1,2]

	Unstandardized Coefficients			
Independent Variables	B	Std. Error	Beta	T Value
Constant	6,537.42	624.94		10.46*
Year of Highest Degree	–3.27	0.32	–0.53	–10.38*
"Disillusioned Scientist"	–4.90	3.22	–0.08	–1.52
"Administrator"	3.45	2.77	0.05	1.25
"Pure Scientist"	5.52	2.81	0.09	1.97*

*Significant at the 0.05 level.
[1]ANOVA: F value = 43.25 ($p < 0.0001$)
[2]Adjusted R Square = 0.315

publish greater numbers of publications, controlling for year of highest degree. On the other hand, the "deficit model" argues that female scientists are less productive than male scientists because they have fewer opportunities than men do throughout the course of their careers (Sonnert & Holton, 1995), that is, there are legal, political, and social structural obstacles that hinder female scientists from attaining the level of career success that male scientists (on average) achieve. To measure some sense of whether female scientists think of their work environments differently than male scientists, the researchers were asked to respond to 14 Likert-type statements that described their scientific work environment and work habits:[5]

- Generally, I prefer to stick with a research topic rather move from topic to topic as new interests or opportunities emerge.
- My own scientific curiosity is the sole consideration in my choice of research topics.
- In my immediate work environment scientists are eager to discuss their work with one another.
- I'd rather have a much higher citation rate than a much higher salary.
- My scientific work is the most important thing in my life.
- I feel that I am now (or soon will be) a leading researcher in my field.
- My colleagues in this department appreciate my research contributions.
- I am satisfied with my job.
- I am satisfied with my personal life (i.e. everything other than the job).
- At my current institution I am discriminated against on the basis of my sex.
- At my current institution I am discriminated against on the basis of my race, ethnicity, religion, or national origin.
- My family is more important to me than my work.
- I think I am paid about what I am worth in the academic market.
- I am more interested in developing fundamental knowledge than in the near-term economic or social applications of science and technology.

Five of the fourteen work environment variables yielded significantly different results for male and female scientists (see Table 7). First, the female scientists were significantly more likely to feel discriminated against at their current institution on the basis of their gender. The male scientists were significantly more likely to (1) feel that scientific curiosity was their sole consideration when choosing research topics, (2) feel that they are (or soon will be) a leading researcher in the field, (3) feel satisfied with their personal life, and (4) think they are paid what they are worth in the academic market. Clearly, these results indicate that the female sci-

Table 7. T-test for Work Environment Variables

Work Environment Variables[a]	Mean for Males	Mean for Females	T Value
Generally, I prefer to stick with a research topic rather move from topic to topic as new interests or opportunities emerge	2.33	2.33	−0.03
My own scientific curiosity is the sole consideration in my choice of research topics	2.67	2.41	−2.15**
In my immediate work environment scientists are eager to discuss their work with one another	3.25	3.19	−0.63
I'd rather have a much higher citation rate than a much higher salary	2.52	2.75	1.30
My scientific work is the most important thing in my life	2.25	2.14	−0.83
I feel that I am now (or soon will be) a leading researcher in my field	3.07	2.75	−2.73**
My colleagues in this department appreciate my research contributions	3.19	3.05	−1.09
I am satisfied with my job	3.33	3.28	−0.47
I am satisfied with my personal life (i.e. everything other than the job)	3.38	3.21	−1.68*
At my current institution I am discriminated against on the basis of my sex	1.14	1.83	5.87**
At my current institution I am discriminated against on the basis of my race, ethnicity, religion, or national origin	1.19	1.26	1.05
My family is more important to me than my work	3.34	3.29	−0.46
I think I am paid about what I am worth in the academic market	2.74	2.46	−2.36**
I am more interested in developing fundamental knowledge than in the near-term economic or social applications of science and technology	2.88	2.72	−1.32

[a]Reported with a Likert-type Scale, where 1 = not relevant, 2 = not important, 3 = somewhat important, 4 = very important.

*Significant at the 0.10 level.

**Significant at the 0.05 level.

entists have (or perceive that they have) different work environments and incentives than the male scientists.

Again, to reduce the data, and to infer possible work environment trends from aggregations of the individual work environment variables, I factor analyzed the responses to the above 14 statements. As with the previous factor analysis, I used principal components analysis (with a varimax rotation, imposing an orthogonality constraint) and the factor dimensions were extracted to the level of one eigenvalue. The results of the factor analysis yielded five dimensions—or five different perceptions of work environment.[6] The results of the factor analysis for the work environment variables are presented in Table 8. The five factors accounted for about 59% of the total variance in the work environment construct. The first work environment trend that emerged was that of the "Academic Leader." This factor accounted for 13.5% of the total variance (after rotation). The items with the strongest loadings on this factor generally represented a work environment that included internal and external acknowledgement of leadership (e.g., researchers who felt that they were leaders in their field and had colleagues who appreciate their contributions) and personal satisfaction (e.g., researchers who were satisfied both with their jobs and their personal lives). The second work environment trend was embodied by the "Victim of Discrimination," which accounted for 13.1% of the

Table 8. Principal Components Analysis of Work Environment Variables

Likert-Type Statements Describing Scientist's Work Environment	Component[1]				
	1	2	3	4	5
I feel that I am now (or soon will be) a leading researcher in my field	0.61				
My colleagues in this department appreciate my research contributions	0.59				
I am satisfied with my job	0.75				
I am satisfied with my personal life (i.e., everything other than the job)	0.65				
At my current institution I am discriminated against on the basis of my sex		0.79			
At my current institution I am discriminated against on the basis of my race, ethnicity, religion, or national origin		0.82			
My scientific work is the most important thing in my life			0.73		
My family is more important to me than my work			–0.82		
I think I am paid about what I am worth in the academic market			–0.31		
Generally, I prefer to stick with a research topic rather move from topic to topic as new interests or opportunities emerge				0.65	
My own scientific curiosity is the sole consideration in my choice of research topics				0.58	
I am more interested in developing fundamental knowledge than in the near-term economic or social applications of science and technology				0.75	
In my immediate work environment scientists are eager to discuss their work with one another					0.65
I'd rather have a much higher citation rate than a much higher salary					0.75

Factor 1 = "Academic Leader"
Factor 2 = "Victim of Discrimination"
Factor 3 = "Loner Scientist"
Factor 4 = "Basic Scientist"
Factor 5 = "Networker"
[1]Principal Components Analysis; Rotation Method: Varimax

total variance. The items with the greatest loadings on this factor represented work environments that were discriminatory (e.g., researchers who felt that they were discriminated against for their gender, race, ethnicity, religion or national origin). The "Loner Scientist" personified the third work environment trend—this factor accounted for about 12% of the total variance. The statements with the greatest loadings on the "Loner Scientist" factor generally represented a work environment where science held extreme importance (e.g., the feeling that science is the most important thing in one's life), professional dissatisfaction existed (e.g., researchers do not feel that they are paid what they are worth), and reduced familial commitment was present (e.g., family is not more important than their work).

The "Basic Scientist" factor embodied the fourth work environment trend, which accounted for 10.8% of the total variance. The statements with the strongest loadings on this factor represented work environments that were traditional (e.g., researchers wanting to stick with one research topic that is guided by scientific curiosity rather than move from topic to topic as new interests emerge) and focused on the generation of basic science knowledge (e.g., researchers were more interested in developing fundamental knowledge than economic or social application

Table 9. OLS Regression Analysis Dependent Variable: Number of Publications (Articles, Books and Book Chapters Only)[1,2]

	Unstandardized Coefficients			
Independent Variables	B	Std. Error	Beta	T Value
Constant	7,684.70	601.57		12.77*
Year of Highest Degree	−3.84	0.30	−0.54	−12.67*
Academic Leader	9.78	3.27	0.13	3.0*
Victim of Discrimination	1.53	3.15	0.02	0.49
Loner Scientist	1.74	3.17	0.02	0.55
Basic Scientist	6.75	3.16	0.09	2.14*
Networker	3.38	3.14	0.04	1.08

*Significant at the 0.05 level.
[1]ANOVA: F value = 38.06 ($p < 0.0001$)
[2]Adjusted R Square = 0.358

of science and technology). The fifth work environment trend was personified by the "Networker," which accounted for 9.6% of the total variance. The items with the greatest loadings on the "Networker" factor represented strong social interactions at work (e.g., researchers had an immediate work environment in which other scientists were eager to discuss their work with one another) and a strong desire to interact with others in the academic community (e.g., researchers would rather have a higher citation rate than a much higher salary).

After completing the factor analysis, I calculated the factor scores, which again facilitated the use of the work environment dimensions as independent variables in regression analysis. I used regression analysis to determine the level of correlation between work environment trends and number of publications, controlling for the year of the highest degree. The results of this regression analysis are presented in Table 9. When controlling for year of highest degree, two work environment trends were good predictors of the total number of publications: the "Academic Leader" and the "Basic Scientist." Researchers whose research environment was embodied by the "Academic Leader" produced about 9.8 more publications than other researchers, controlling for year of highest degree. The researchers whose work environment was personified by the "Basic Scientist" dimension produced about 6.8 more publications than other researchers, when controlling for year of highest degree. For this analysis, the work environment trends embodied by the "Victim of Discrimination," the "Loner Scientist," and the "Networker" did not lead to significantly higher levels of publications.

Discussion and Conclusions

Not unlike past studies focusing on productivity in the sciences and engineering, female scientists in our sample did produce fewer publications than the male scientists. However, like the results found by Nakhaie (2002), this research demonstrates that the difference between publication rates for male and female scientists became insignificant when controlling for discipline, marital status, number of children, and years since highest degree. This is particularly interesting because the sample of researchers in this study were not traditional department-based faculty; rather, they were center-affiliated researchers. The results of this analysis align with another recent study (Corley & Gaughan, 2005) which demonstrates that interdisciplinary science centers might level the productivity playing field for male and female scientists.

To go beyond simply measuring number of publications across gender, I then analyzed data on career strategies and perceptions of scientific work environments. The purpose of this analysis was to determine if either career strategy or work environment impacted productivity rates for the scientists. Based on the factor analysis of nine statements related to career strategies, I discovered three underlying career strategy dimensions: the "Disillusioned Scientist," the "Administrator," and the "Pure Scientist." When controlling for the year of highest degree, the only career strategy dimension that was a good predictor of research productivity was the "Pure Scientist." This result implies that researchers who take a more traditional approach to pursuing research careers in scientific fields are more successful when it comes to publishing their results. Scientists who pursue other career strategies lag behind the "Pure Scientist" in number of total publications. One of the most important components of the "Pure Scientist" dimension was the statement that a chief career goal is to obtain a position in the best research institution possible. Interestingly, the males in our sample were more likely to assign a high level of importance to this goal than female scientists were, meaning that both males and females might choose the "Pure Scientist" career strategy, but males were more likely to do so. This difference in career strategies could be one of the underlying factors that differentiated male and female publication rates in our sample.

Using the results of the factor analysis of fourteen statements related to perception of scientific work environments, I found five underlying work environment dimensions that can be best described by researcher types: the "Academic Leader," the "Victim of Discrimination," the "Loner Scientist," the "Basic Scientist," and the "Networker." Two of these dimensions proved to be good predictors of the total number of publications: the "Academic Leader" and the "Basic Scientist." The four statements with the strongest loadings on the "Academic Leader" factor were all statements on which the male scientists scored higher than the female scientists did (with males scoring significantly higher for two of the four statements). Male scientists also scored higher on two of the three statements with the strongest loadings on the "Basic Scientist" factor (with male and female scientists scoring the same on the third statement). These results demonstrate that there are clear individual career strategies and scientific work environments that lead certain scientists to be more productive in federally funded science centers—and that the male scientists in this sample scored higher on these dimensions than the female scientists.

Based on the analyses presented here, the scientific work environment that is most conducive to high productivity within these centers focuses on one of two approaches: either maintaining a traditional, basic science approach to conducting research that discourages moving from one topic to another (or potentially pursing interdisciplinary research, which can be in conflict with traditional, basic science) *or* working in a satisfying and supportive work environment in which colleagues (both internal and external to the university) value each other's contributions. As with the career strategy construct, the female scientists in the sample scored lower than the male scientists on six of the seven statements that were linked with the work environment factors that were good predictors of publication rates (they scored the same as the male scientists on the other statement).

These results have a number of implications for interdisciplinary science centers, in particular, and for United States science policy, in general. First, when controlling for variables like marital status and number of children, gender differences in productivity rates disappear for center-affiliated researchers. This finding warrants additional study to determine if federally funded science centers can provide one institutional solution for helping women attain productivity rates similar to male scientists.

Second, the results of this study show there are underlying factors related to career strategies and scientific work environments that are affecting publication rates—and those factors may or may not be linked to gender (regardless, they *are* correlated for this sample). These results give rise to two important questions: "to what degree are scientific work environments in federally funded science centers less beneficial for the productivity of female scientists and junior-level scientists?" (i.e., are women scientists in centers simply working harder and longer to catch up with their male peers?) and "to what degree are traditional career strategies being rewarded in federally funded science centers, even though many of those centers focus on non-traditional, interdisciplinary research?"

While the results presented in this paper cannot fully answer both questions, the results do demonstrate that certain career strategies and scientific work environments lead to higher levels of scientific productivity—and that more male scientists in this sample were aligned with the "successful" career strategy and were working in a "successful" work environment. As major funding organizations continue to increase levels of funding for interdisciplinary science centers, it will be increasingly important to ask how the institutional structure of these centers can further aid female scientists as they struggle to catch up with productivity rates of their male colleagues. The results clearly show that women were significantly more likely to feel discriminated against within center-based research positions. This result is of great concern since many science centers already have such low numbers of female scientists. In addition to comparing differences across genders, we need to also ask in future studies whether interdisciplinary centers are sufficiently supportive of the scientific success of junior-level researchers and foreign-born researchers.

Early United States science policies focused on helping scholars at the beginning of their careers (e.g., making sure female and minority scientists are sufficiently considered for open job opportunity), without thoughtful regard for the structure of a successful research work environment and career strategy. But these early-career checks neglect to address the day-to-day work environment and career strategy changes that help talented scientists make the transition from an early, promising career to a full-blown, productive career. The results of this study indicate that the best way to get to a high level of productivity within many federally funded science centers is to pursue a traditional scientific research career with traditional research questions—regardless of the supposed interdisciplinary nature of the mission of the science center. Certainly many scholars would agree that funding interdisciplinary science centers is good for science, but as the National Science

Foundation (and other major funding organizations) continue to increase financial support for interdisciplinary science centers, it will be important to make sure that the institutional structure of those centers is helping all scientists, not just a few.

Notes

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2 Hereafter the term "scientists" will be used, rather than the more cumbersome "scientists and engineers." But the study includes data for both scientists and engineers and the distinction is made when needed.

3 Based on a comparison of means t-test, this difference is not statistically significant at the 0.05 level (p value = 0.185).

4 The respective dimensions are based on factors that loaded the strongest.

5 The statement that prefaced the 14 work environment statements in the questionnaire was worded in the following way: "Please indicate the extent to which you agree or disagree with the following statements." The possible responses were 1 = not relevant, 2 = not important, 3 = somewhat important, and 4 = very important.

6 The respective dimensions are based on factors that loaded the strongest.

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