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Gender Inequality within the U.S. Land-Grant Agricultural Sciences Professoriate

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ABSTRACT

This paper focuses on gender inequality in the agricultural sciences in colleges of agriculture at U.S. land-grant universities. We ask two questions: (1) What degree of gender inequality exists in the agricultural sciences? (2) Can gender inequality be attributed to differences in human capital; professional networking; means of scientific production[1]; and/or, research productivity? Drawing on data from a 2005 nationwide survey of land-grant agricultural scientists, we find evidence of significant gender inequality despite few gender differences in scientists' human capital, professional networking, means of scientific production, and research productivity. Our most robust findings relate to gender differences in scientists' doctoral training, farming experience, and ties with private industry. Male agricultural scientists' stronger linkages with land-grant universities, the farming world, and private industry may result in superior career outcomes (in terms of promotion and salary) compared to their female counterparts.

KEYWORDS

Gender inequality; Women scientists; Agricultural sciences; Land-grant universities

Gender Inequality within the U.S. Land-Grant Agricultural Sciences Professoriate

INTRODUCTION

It is widely acknowledged that gender inequality exists in academia, especially in the sciences (see, e.g., Cole, 1979; Fox, 1991,1995, 2001; Rossiter, 1982, 1995; Zuckerman and Cole, 1975; Zuckerman et al., 1991; Long, 2001; National Science Foundation [NSF], 2003). Women faculty are under-represented in terms of numbers (especially in the senior ranks), earn less, and are promoted less frequently to senior ranks. This paper focuses on gender inequality in an understudied branch of the U.S. professoriate: the agricultural and life sciences (hereafter agricultural sciences) in colleges of agriculture at U.S. land-grant universities.

Characterized by a tripartite mission of teaching, research, and outreach, land-grant universities are a unique component of U.S. higher education (National Research Council [NRC], 1996; National Association of State Universities and Land-Grant Colleges [NASULGC], 2000). The land-grant system began with the passage of the Morrill Act (1862) which granted states public lands for the creation of colleges of agriculture and mechanical arts. Subsequent federal mandates established the state agricultural experiment stations (Hatch Act of 1887) and cooperative extension services (Smith-Lever Act of 1914) (NRC, 1995). The agricultural experiment stations have served as 'the model for public encouragement of scientific research' and cooperative extension as 'the prototype for applying research findings to relevant practical problems' (Campbell, 1998: 164). Land-grant agricultural research and educational outreach programs have played a direct role in most progressive developments in agriculture (Campbell, 1998; NRC, 1995). Given the unique organizational structure and 'mission' orientation of land-grant colleges of agriculture, we expect the agricultural sciences to differ from other fields of study (see Smith-Doerr 2004 on gender inequality and organizational context).

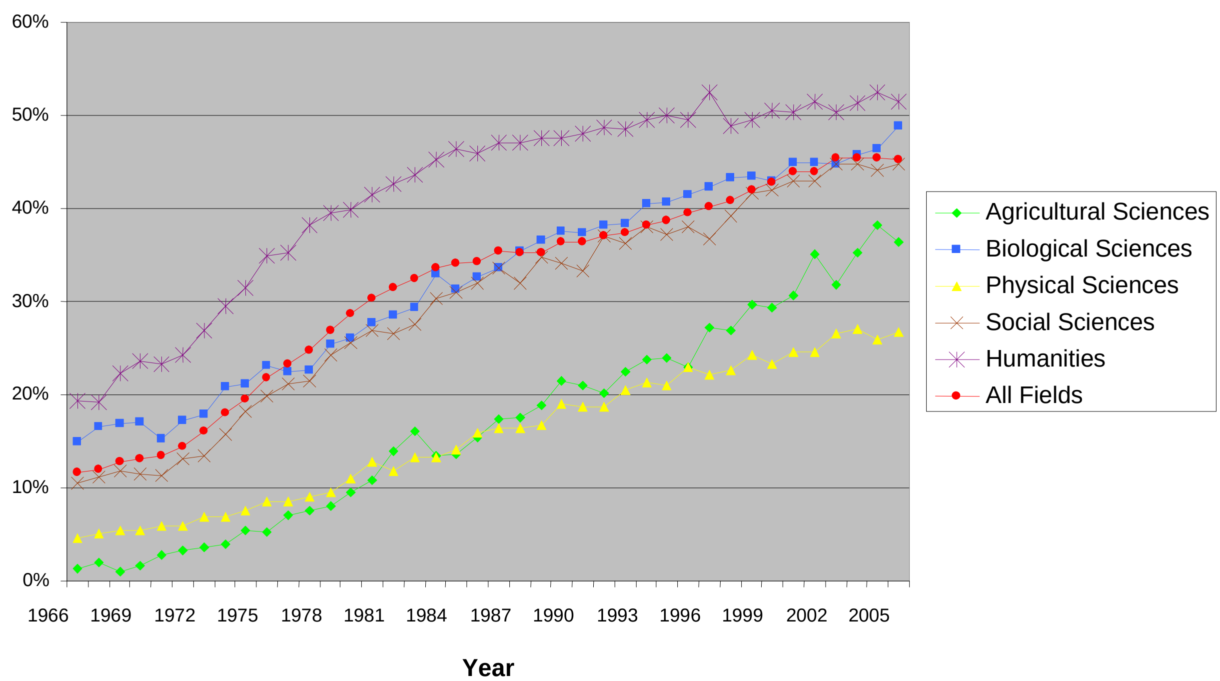
In this exploratory study, we ask two central questions: (1) What degree of gender inequality exists in the agricultural sciences at land-grant universities? (2) Can gender inequality be attributed to differences in human capital; professional networking (or social capital); means of scientific production; and/or, research productivity? Drawing on data from a 2005 nationwide survey of land-grant agricultural scientists, we find evidence of significant gender inequality despite few gender differences in scientists' human capital, professional networking, means of scientific production, and research productivity. Our most robust findings relate to gender differences in scientists' doctoral training, farming experience, and ties to private industry.

GENDER INEQUALITY IN THE AGRICULTURAL SCIENCES

Male dominance of the agricultural sciences has been well documented (NRC, 1995; Rossiter, 1979, 1982, 1995; Busch and Lacy, 1983; Buttel and Goldberger, 2002). A National Research Council report states: 'women are a significantly larger percentage in agricultural science today than 20 years ago; however, their presence is still minimal in relation to that of women in either life or natural sciences' (1995: 55). Buttel and Goldberger (2002) offered one of the first comprehensive studies of the gendered nature of public agricultural research. They found significant gender differences in scientists' educational backgrounds, academic appointments, research environments, linkages with private industry, and attitudes about consumer health, biotechnology, and university-industry relationships. They concluded that 'significant aspects of gender inequality remain in the agricultural sciences at land-grant institutions' (p.40).

Data from the National Science Foundation's Annual Survey of Earned Doctorates provide an indication of gender gaps in the receipt of doctoral degrees for different fields of study. Figure 1 reports data from the Annual Survey of Earned Doctorates for 1966 to 2005 (NSF, 2007). Women made inroads in all academic fields, including the agricultural sciences, over the past 40 years. The percentage of doctorates in the agricultural sciences awarded to women increased from 1% in 1966 to 36% in 2005. However, the percentage of agricultural sciences doctorates awarded to women has been consistently lower than the percentage of doctorates awarded to women in the biological sciences, social sciences, humanities, and all indicate 32% of doctoral scientists in the agricultural, biological, and environmental life sciences at universities and four-year colleges[2] are women (NSF, 2006a).

Figure 1. Percentage of U.S. Doctorates Awarded to Females, 1966-2005 (Data Source: NSF Survey of Earned Doctorates)



POSSIBLE EXPLANATIONS FOR GENDER INEQUALITY IN THE AGRICULTURAL SCIENCES

Obtaining the necessary human capital, engaging in professional networking, having access to the means of scientific production, and exhibiting a high level of research productivity are important contributors to successful scientific careers. Gender inequality (in terms of promotion, tenure, and salary) may result if women and men differ significantly in any of these four areas. This section reviews the literature on human capital, professional networking, means of scientific production, and research productivity as explanations for gender inequality in the sciences, in general, and the agricultural sciences, in particular.

Human Capital

Human capital refers to individual-level characteristics that strengthen a person's ability to earn a living and achieve community, family, and self-improvement goals. It includes health, formal education, skills, intelligence, leadership, and talents (Flora and Flora, 2008). Advances in human capital have been linked to a variety of outcomes at the individual, organizational, community, and regional levels. Research has shown that while intelligence, measured in terms of Intelligence Quotient (IQ), may be a prerequisite for advanced training, once a higher degree is obtained, differences in intelligence do not predict subsequent measures of rewards (Cole and Cole, 1973; Sonnert and Holton, 1995). In fact, while women receive fewer rewards than men in the sciences, their measured ability is higher. In a variety of scientific disciplines (e.g., chemistry, biology, psychology, and sociology) female Ph.D.-holders have slightly higher IQs than their male counterparts (Cole, 1979). While IQ may be a sufficient indicator of ability for some disciplines, we contend it is an insufficient indicator of ability in the agricultural sciences. As we discuss below, additional human capital measures, such as doctoral prestige, postdoctoral experience, and farm background, must be considered.

While certain measures of intelligence (e.g., IQ) may not be accurate predictors of rewards, research has demonstrated that credentials can influence promotion and salary. A substantial body of work has found that the quality of a scientist's graduate training has important career consequences (see Long and Fox, 1995). Conceptions of scientific roles, work style, and performance expectations develop during graduate school (Zuckerman, 1977). Furthermore, graduate schools differ substantially with respect to the quality of facilities, intellectual stimulation provided by colleagues, professors, and guest speakers, and motivation to succeed (Allison and Long, 1990). Therefore, it makes sense to examine the effect of graduate school background on differential attainments by sex.

Research has shown that men and women in certain disciplines (e.g., mathematics) differ in the likelihood of having received advanced degrees from top ranking universities (NRC, 1983; Long, 2001). Female Ph.D. recipients in these disciplines on average attend less prestigious schools compared to male Ph.D. recipients. However, in other fields (e.g., engineering, social sciences) gender differences are much smaller (Fox, 1995; Long, 2001). While gender differences in the prestige of Ph.D. programs have been analyzed for several disciplines, the agricultural sciences are often excluded from such analyses. Moreover, most researchers concerned with the effect of Ph.D. program prestige on career outcomes examine the rankings of graduate programs and the quality of associated faculty. While the ranking and quality of faculty associated with Ph.D. programs may be good predictors of career rewards for some disciplines, additional indicators may be appropriate for the agricultural sciences. The agricultural sciences are located primarily at land-grant universities, and therefore the receipt of a degree from a land-grant school, especially a top ranking land-grant school, may be a better indicator of the quality of graduate education for faculty in the agricultural sciences (Busch and Lacy, 1983).

Postdoctoral academic training and post-Ph.D. non-academic employment (e.g., employment in private industry or government) are other ways to accumulate human capital. These experiences may influence future career outcomes because they allow young scientists to access research facilities, establish research programs, and make connections with new colleagues. An equally important contributor to human capital, especially for agricultural scientists, is a farm background. Agricultural scientists are far more likely than other types of scientists to come from a farm background (Busch and Lacy, 1983; Buttel and Goldberger, 2002). These scientists can certainly draw on prior agricultural knowledge to excel in their academic careers.

Professional Networking

Graduate school rankings do not address the *dynamics* of graduate education, such as the quality of graduate assistantships (Hornig, 1987), which may lead to different opportunities to collaborate on research projects (Fox, 1995). Collaborating with mentors is a particularly important factor in career success because it influences predoctoral productivity, job placement, and productivity later in one's career (Long and McGinnis, 1985). Studies of graduate students indicate that women do not interact with faculty members and advisers as often as male graduate students (Holmstrom and Holmstrom, 1974; Kjerulff and Blood, 1973).

Oftentimes, female graduate students feel their graduate advisors do not tap into their social networks on their behalf as they do for male graduate students (Sonnert and Holton, 1995). This lack of assistance may lead female graduate students to have less future interaction with mentors compared to male students. The lack of interaction with advisors during graduate school may persist during academic employment and negatively influence career advancement and other rewards. Therefore, one must consider the role of professional networking in achieving academic rewards. As Fox (2001: 660) aptly states: 'if women are constrained within the social networks of science ... this restricts their possibilities ... to show the marks of status and performance in science'.

Professional networking can be viewed as a form of social capital. Several studies link the development of social capital to achievement, whether at the individual (e.g. Bourdieu, 1979, 1980; Coleman, 1988), community (e.g., Flora and Flora, 1993; Crowe, 2006, 2007), or regional (e.g. Putnam, 1993) level. While myriad definitions of social capital exist, a common element in most definitions is social networks. Social networks are the connections between individuals, organizations, and communities that allow for the transfer of information that can be harnessed to help achieve certain goals. With respect to social capital at the individual level, Coleman (1988) and Bourdieu (1979, 1980) link an individual's social ties to individual-level outcomes such as educational attainment and wealth. Social ties can also influence professional outcomes in academia, such as promotion and salary (Agneir, 2002; Sonnert and Holton, 1995; He et al., 2009).

Scientists continually test and revise research. The exchange of ideas occurs informally (e.g., chatting in the hallway, attending a social event, or sharing a meal with colleagues during an academic conference) and formally through manuscript and book reviews, conference presentations, and other types of scholarly activities. In this manner, science is more 'social' than the arts or humanities (Fox, 1991, 1995, 2001). Scientific research is more likely to be performed by teams rather than isolated individuals (Wuchty et al., 2007). Science can be extremely insular, however, making it imperative to be at the center of scientific discussions to hear the latest research findings. However, 'more often than men, [women] remain outside the heated discussions, inner cadres, and social networks in which scientific ideas are aired, exchanged, and evaluated' (Fox 1991: 195). Interviews with women at all stages of their scientific careers have shown that women are excluded from the most important scientific meetings and research collaborations and, consequently, are deprived of information essential for career advancement (Angier, 2002; Sonnert and Holton, 1995). Many scientific endeavors require research collaborations, and male scientists often feel more comfortable working with male rather than female colleagues (Angier, 2002; NSF, 2003).

Women scientists may also be excluded from the latest research findings because they are less likely than men to hold positions as editors, officers of professional associations, and grant reviewers (Fox ,1991; Kashet et al., 1974; Waller et al., 1998). In addition, women are less likely to be invited to lectures or collaborate outside of their institutions (Angier, 2002; Kashet et al., 1974; Kurichi et al., 2005), thus depriving them of additional opportunities to network with colleagues. Research collaborations often lead to coauthored works, which often fare better in the publication process as they provide checks against error (Presser, 1980) and are more likely to result from funded research (Heffner, 1980). Studies also show that co-authored works are cited more often than sole-authored articles (Wuchty et al., 2007).

While networking with academic colleagues can affect advancement and salary, networking with individuals and groups outside of academia may also determine rewards, especially in the *public-oriented* agricultural sciences in land-grant colleges of agriculture. Agricultural scientists' extraorganizational linkages include relationships with federal, state, and local government, commodity associations, non-profit associations, private corporations, and international organizations. These linkages help scientists 'increase their research support, exchange information, increase their visibility and prestige, and, not least, increase their incomes' (Busch and Lacy, 1983: 149).

Means of Scientific Production

The third potential explanation for gender inequality within the land-grant agricultural sciences professoriate centers on gender differences in the means of scientific production, such as the amount and type of research funding, number of employees, and amount of time devoted to research activities. These resources facilitate research but are often unequally distributed between male and female scientists. Cole and Zuckerman (1984) emphasize the importance of the social organization of scientific laboratories and academic departments, as well as the allocation of time to research versus teaching. The Committee on the Education and Employment of Women in Science and Engineering suggests that gender differences in rewards may be explained entirely by access to the means of scientific production overlooked by earlier research: 'For the specific case of science faculty, factors such as access to appropriate research facilities, division of time between undergraduate and graduate teaching responsibilities, and especially availability of graduate and other research assistants may be of greater significance than rank or other variables' (1979: 87).

Academic institutional structure influences the allocation of faculty work hours (to research, teaching, advising, etc.), as well as the availability of research assistants, funding, and equipment. However, men and women at the same institution may experience different constraints and opportunities. Fox (1995) finds that in M.A. and Ph.D. programs, women give significantly lower rankings than men to the availability of resources. In departments with Ph.D. programs, female faculty report significantly higher undergraduate teaching loads than men. However, Xie and Shauman (2003) find that the average teaching loads of male and female scientists have become more equitable in recent years, with women teaching slightly more hours than men. Similarly, they find that gender differences in research funding have also narrowed considerably, with roughly the same percentage of men and women receiving federal, state, and institutional funding.

While Xie and Shauman (2003) show that roughly the same percentage of male and female faculty receive federal, state, and institutional funding for their research, they do not examine differences in the amount of funding men and women receive or the quality of research facilities provided. Feldt (1986) finds differences in the means of scientific production provided to male and female faculty at the same university. Specifically, male and female assistant professors at the University of Michigan received different treatment: men received more start-up funds and better facilities and equipment compared to women.

Research Productivity

Lastly, we consider faculty research productivity as a possible explanation for gender inequality in the agricultural sciences. This explanation posits that male faculty are more productive, so they earn more and are promoted more readily than female faculty. Understanding gender differences in research productivity is imperative when assessing gender differences in salaries and promotions in academia.

Research productivity refers to the amount of 'research output' in a period of 'exposure' (Xie and Shauman, 2003). The majority of studies which have focused on faculty research productivity by gender have found that, on average, men produce more research output than women (see Toutkoushian, 1999; Long, 2001; Xie and Shauman, 2003; NSF, 2003 for reviews). Research output is typically measured by the number of publications, either self-reported or found in bibliographic searches. Cole and Zuckerman (1984) estimate that men published nearly 50% more than women. Other researchers (e.g. Long, 1992; Ward and Grant, 1995; Xie and Shauman, 1998; Zuckerman, 1991) have supported this finding. The gender gap in number of publications differs by academic discipline (Helmreich et al., 1980; Reskin, 1978; Fox, 1995). However, by analyzing scientific productivity over time, Xie and Shauman (1998, 2003) show that gender differences in productivity have declined.

Past research has examined several factors that may cause women to publish less frequently than men. These factors include ability, doctoral and postdoctoral training, the organizational context of employment, and discrimination (Long, 2001). Female scientists may also publish less frequently than male scientists because of a need to see the 'whole picture' (Goldberg, 2002). Delaying publication until a complete understanding of a problem is known not only results in fewer publications but can adversely affect one's chances for promotion and tenure.

As for formal presentations, women scientists believe they are provided with far fewer chances to present their findings and ideas to influential audiences of their peers, an important method for gaining scientific influence, and when they do present they are scrutinized more heavily than men (Angier, 2002). This high level of scrutiny makes female scientists less likely to present at conferences unless their talks are in their area of expertise and well prepared.

Research is limited on gender differences in research productivity within the land-grant agricultural sciences professoriate. Although Busch and Lacy (1983) discuss publication frequency as a measure of research productivity for agricultural scientists, they do not examine gender differences in productivity. In contrast, Buttel and Goldberger (2002) examine publication rates among agricultural scientists in the early 1990s and find significant gender gaps in the number of research bulletins/reports and authored/edited books. Their research also indicated a closing of the gender gap from the late 1970s to the 1990s in the production of journal articles by agricultural scientists.

Because of the increasing 'commercialization' of research and subsequent changes in academic reward structures at land-grant and other institutions (Owen-Smith and Powell, 2003; Slaughter and Rhoades, 2004), scholars have begun employing patents, products, and start-up companies as measures of research productivity. Whittington and Smith-Doerr (2005, 2008) find that women scientists, even when controlling for education and other factors, engage in less commercial work and produce fewer commercial outputs than their male counterparts. Ding et al. (2006) analyze data from over 4,000 faculty members in the life sciences and conclude that women patent at about 40% of the rate of men. Patenting activity differs by faculty cohort: 'among the most senior faculty, a large gender gap persists, reinforced by women's limited commercial networks and traditional views of academic careers. Younger cohorts widely embrace patenting, although a gender gap remains' (Ding et al., 2006: 667).

METHODS

Survey Procedures

This paper relies on data from a survey of faculty members in departments typically associated with colleges of agriculture at the '1862' land-grant universities[3]. During September–October 2004, Goldberger and a team at the University of Wisconsin-Madison derived a sampling population of approximately 12,000 full, associate, and assistant professors from online faculty listings in the traditional crop and animal production sciences; environmental and natural resource sciences; agricultural social sciences; food and nutritional sciences; basic biological sciences; and, agricultural engineering at 53 land-grant universities. Goldberger et al. used a simple random sampling design (Microsoft Excel's Random Number Generator) to obtain a nationally representative sample of 1,963 professors.

During February–April 2005, a web-based survey was conducted using a modified Dillman (2000) method. Introductory letters were sent by regular mail followed by four contacts via e-mail. E-mail correspondence included instructions for participating in a survey entitled 'Modern Agricultural Science in Transition: A Survey of U.S. Land-Grant Agricultural and Life Scientists'. The survey was designed as a replication and extension of the surveys used by Busch and Lacy (in 1979) and Buttel (in 1989 and 1996) in their analyses of land-grant agricultural research (Busch and Lacy, 1985; Buttel and Goldberger, 2002)

We excluded 181 individuals from the sample because of death, retirement, unknown addresses, exit from research, and non-agricultural departmental affiliations (e.g., family studies, marine science, zoology). The result was a corrected sample of 1,782 agricultural and life scientists. We received 1,027 completed surveys resulting in a 57.6% response rate. We eliminated an additional 80 respondents because of USDA-Agricultural Research Service (ARS) employment[4], off-campus appointments, and primary affiliations with non-agricultural departments. Our final sample included 183 female and 774 male faculty members.

Data Analysis Procedures

The primary objective of our analysis is to explore the relationship between gender and five sets of variables: measures of inequality; human capital; professional networking; means of scientific production; and, research productivity. Measurement details for all variables are presented below. We use Pearson chi-square tests and two-tailed *t*-tests to determine whether male and female agricultural scientists differ significantly in terms of our variables of interest. These tests are designed to test for independence between two variables. The null hypothesis is that the two variables are statistically independent. As this is an exploratory study, we favor a simple bivariate approach over the use of multivariate models that rely on a limited number of dependent and independent variables. Future analysis of our land-grant agricultural scientists data will draw on the findings reported below to develop multivariate models that can investigate the relative importance of human capital, professional networking, means of scientific production, and research productivity variables on gender inequality (e.g., pay differences or gender segregation).

Gender inequality variables

Gender inequality within the U.S. professoriate is often measured in terms of the number of male versus female faculty members, gender differences in rank and tenure status, and the gender gap in earnings. Therefore, we examine four indicators of gender inequality in the agricultural sciences: (1) the percentage of male and female professors in academic disciplines typically associated with colleges of agriculture; (2) the academic rank of male and female professors; (3) the tenure status of male and female professors; and, (4) the base and monthly salaries of male and female professors. Rank and tenure status are categorical variables, while salary is a continuous variable.

Human capital variables

We consider five human capital measures: graduate training from a land-grant university; graduate training from a top 10 land-grant university; postdoctoral academic experience; postdoctoral non-academic employment; and, farm background. Land-grant graduate training is a dichotomous variable based on whether or not a respondent received his or her doctoral degree from a '1862' land-grant university. We also consider whether or not a respondent received his or her degree from a top 10 land-grant university. Top 10 status was determined by ranking land-grant universities on three criteria: total State Agricultural Experiment Station research expenditures (USDA CSREES, 2006) the number of doctorates granted in the agricultural sciences, and the number of doctorates granted in the biosciences (NSF 2006b). Following Buttel and Goldberger (2002), we calculated an overall prestige index by weighting these three items equally for each land-grant university. The remaining human capital variables—postdoctoral academic experience, postdoctoral non-academic employment, and farm background—are also dichotomous (yes/no) variables.

Professional networking variables

We consider three professional networking (or social capital) variables—research collaboration, co-authorship, and private industry consulting—that may influence professional career success in the agricultural sciences. Faculty members were asked whether or not they had 'collaborated on a research project in the past year' and 'co-authored a paper or patent in the past year' with university colleagues; private industry scientists; farmers or farm organizations; Cooperative Extension Service staff; non-profit or citizen groups; and, government agencies. These collaboration and co-authorship variables are all dichotomous (yes/no). Respondents were also asked to report the number of university colleagues and private industry scientists with whom they had collaborated and co-authored a paper or patent. Private industry consulting is a dichotomous variable based on whether or not a respondent had engaged in at least one day of consulting for private, for-profit businesses in the year prior to the survey.

Means of scientific production variables

We include three sets of measures of the means of scientific production: research funding, number of employees, and amount of time devoted to research and other work activities. Research funding is a continuous variable based on a direct question about the current annual budget of a respondent's research program. Respondents were then asked to provide approximate percentages (of total research funding) for the following sources of support: Experiment Station funds (model for public encouragement of scientific research); funds from their own university or college; USDA grants and cooperative agreements; National Science Foundation; National Institutes of Health; other federal government funding; state government; commodity organizations[5]; foundations; and, private industry. Respondents were also asked to report current numbers of research program employees, specifically graduate students, postdoctoral fellows, and technicians. Our time allocation variables are based on direct questions about the actual conditions of employment (research, teaching, outreach, and administration), research orientation (basic, applied, and development research), and research activities (grant proposal preparation, grant administration, and actual research work).

Research productivity variables
We include three sets of research productivity variables: publications, formal presentations, and indicators of research commercialization. Survey respondents were asked to report the number of journal articles, authored books, edited books, book chapters, abstracts, and bulletins/reports authored or co-authored over the five-year period (2000-2004) prior to completing the survey. Respondents were also asked to report the number of times they formally presented their research findings to the following groups: own department/university; other universities; academic conferences; farmers or farm organizations; Cooperative Extension Service staff; commodity groups; non-profit or citizens groups; and, private industry. Finally, research commercialization was measured with a question asking respondents whether or not they had generated the following outputs from their research program during 2000-2004: invention disclosures; patent applications; patents issued; patents licensed out; products under regulatory review; products on the market; and, start-up companies.

FINDINGS

Figure 2 presents the percentage of male and female faculty in eight discipline categories for our sample of land-grant agricultural scientists. Women remain extremely under-represented in nearly all discipline categories. Agricultural engineering has the lowest percentage of female faculty (11.5%), while nutrition has the highest percentage of women (58.8%). In all disciplines combined, less than one fifth (19.1%) of professors are women. Sachs (1983: 60) explains that the hierarchical sexual division of labor in the agricultural sciences 'pushes women scientists into domestic concerns, while men study agricultural production'. Thus, it is not surprising to see higher percentages of women in nutrition and food science compared to other disciplines. However, these academic fields tend to make up a relatively small proportion of the total agricultural sciences professoriate; less than ten percent of our sample are nutrition and food science faculty. As Sachs (1983: 61-62) states: 'the agricultural sciences with the greatest scientific *man* power ... are those with the smallest percentage of women' (emphasis in the original).

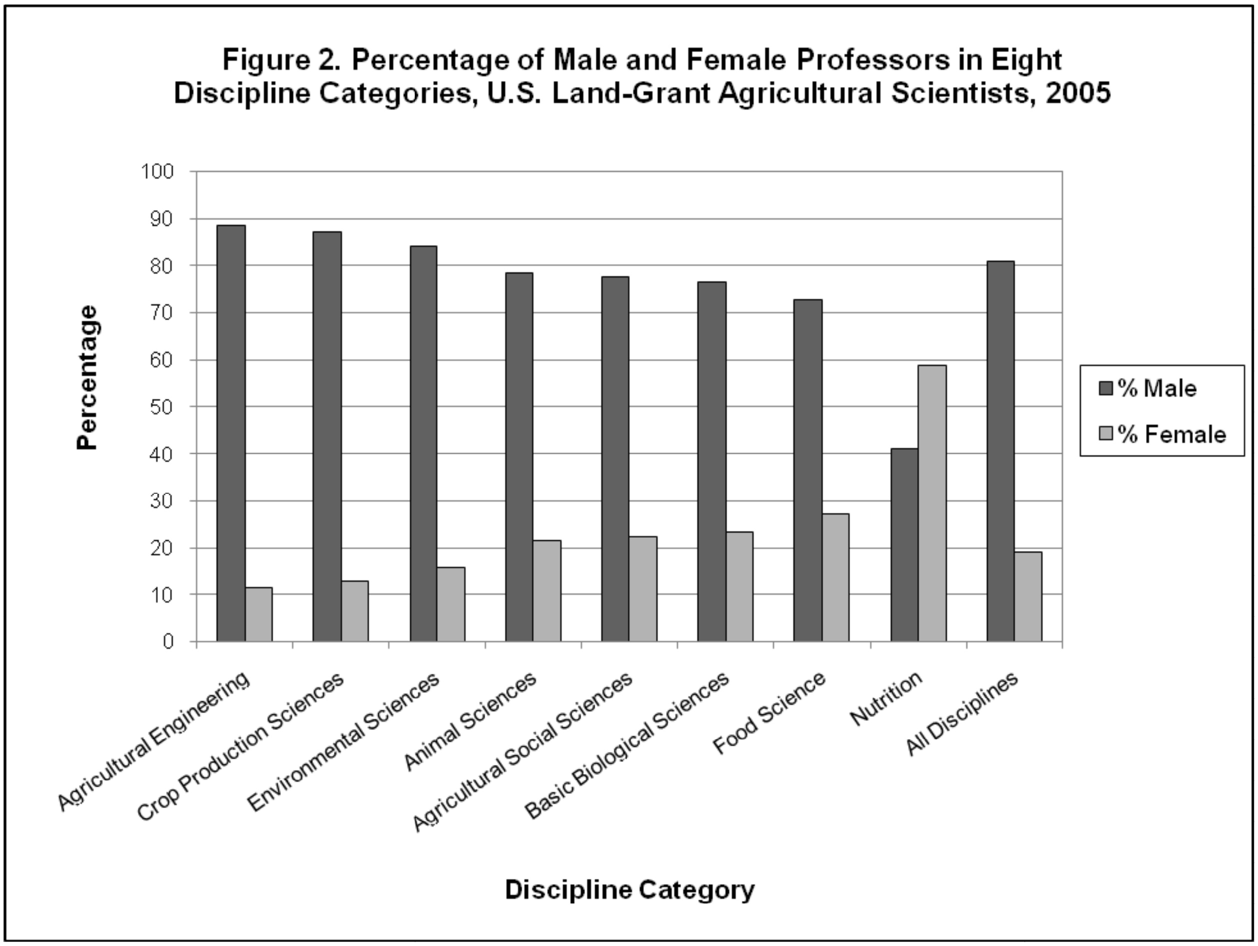


Table 1 reports the percentage distributions for academic rank and tenure status by gender for our sample of land-grant agricultural scientists. Our results indicate that men are concentrated at the highest rank, while women are disproportionately found at the lower ranks. Fifty six percent of male faculty, compared to 33% of female faculty, are full professors. Eighteen percent of male faculty, compared to 34% of female faculty, are assistant professors. These gender differences are statistically significant. Table 1 also shows that over 78% of male professors and only 61% of female professors are tenured. Moreover, female agricultural scientists are more likely than their male counterparts to be in non-tenure-track positions.

We also examine the salaries of male and female survey respondents. Women on average have lower annual base salaries than men: $74,553 compared to $85,754. This gender gap in earnings is statistically significant ($p \leq .001$). However, the length of academic appointments at land-grant universities can vary. Some professors have 9-month (academic year) appointments, while other professors have 10-, 11-, or 12-month appointments. Thus, we divided annual base salary by appointment length to calculate monthly salary. The gender gap in monthly salary—$7,141 for women and $7,832 for men—is also statistically significant ($p \leq .001$).

Table 1: Percentage Distributions for Academic Rank and Tenure Status by Gender, U.S. Land-Grant Agricultural Scientists, 2005

	Men	Women	Chi-Square
Academic Rank			
Assistant professor	18.3	33.9	
Associate professor	25.5	32.8	
Full professor	56.2	33.3	
Total	100.0	100.0	34.652 ***
Tenure Status			
Tenured	78.1	61.0	
Not tenured but on track	18.0	31.9	
Not on tenure track	3.9	7.1	
Total	100.0	100.0	22.843 ***

* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$ (Pearson chi-square test)

Next we explore the gender gaps in salary by academic rank, tenure status, and discipline (see Table 2). We find a statistically significant gender difference in the monthly salaries of tenured professors (the majority of our sample). On average, tenured male professors make approximately $500 more per month than tenured female professors. Table 2 also indicates a statistically significant gender gap in monthly earnings for faculty in agricultural social sciences, crop production sciences, food science, and nutrition. Significant gender gaps in monthly pay range from approximately $800 for crop production science faculty to $2,800 for nutrition faculty. Gender inequality in earnings may simply reflect the concentration of women at lower ranks and men at the highest rank. However, the gender gap in salary remains statistically significant ($p \leq .05$) for associate and full professors in crop production sciences, as well as tenured nutrition faculty.

Table 3 reports the percentage distributions for our five human capital measures. We find a statistically significant gender difference in land-grant graduate training. Nearly 86% of male scientists compared to 78% of female scientists received doctoral degrees from land-grant schools. As men are more likely to have graduated from land-grant universities, it is possible that they have an advantage in establishing themselves in land-grant academic positions. In line with past research on the prestige of doctoral origins for scientists (Long, 2001), we find no statistically significant gender difference in having received a Ph.D. degree from a prestigious (top 10) land-grant university. We also find no significant gender differences in postdoctoral academic experience nor postdoctoral non-academic employment. However, we find a statistically significant gender difference in farm background. Male professors are more than twice as likely to have grown up on a farm and, consequently, to have acquired agricultural skills and knowledge. In sum, our findings suggest minor gender differences in human capital endowments within the land-grant agricultural sciences professoriate. Our results essentially mirror those reported by Buttel and Goldberger (2002) who analyzed data from 1979 and 1996 surveys conducted of land-grant agricultural scientists.

Table 2. Monthly Salary by Gender for Academic Rank, Tenure Status, and Discipline, U.S. Land-Grant Agricultural Scientists, 2005

	Men	Women
Academic Rank		
Assistant professor	5,909	6,066
Associate professor	6,794	6,987
Full professor	8,892	8,397
Tenure Status		
Tenured	8,299	7,819 *
Not tenured but on track	6,155	6,046
Not on tenure track	6,021	5,647
Discipline		
Agricultural engineering	7,796	7,422
Agricultural social sciences	8,455	7,397 *
Animal sciences	7,354	7,541
Basic biological sciences	8,302	7,988
Crop production sciences	7,762	6,953 *
Environmental sciences	7,183	6,733
Food science	7,869	6,408 **
Nutrition	9,490	6,703 ***

* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$ (two-tailed *t*-test)

Chi-square and *t*-test analyses (available from the authors) for our collaboration and co-authorship variables indicate no statistically significant gender differences *except* for the number of private industry scientists with whom respondents had collaborated on a research project. On average, male respondents had collaborated with .82 private industry scientists, while female respondents had worked with .49 private industry scientists ($p = .005$). We also find a significant difference between the percentages of male and female faculty members who reported having consulted for private businesses. Nearly 32% of male scientists and 21% of female scientists consulted for private industry in 2004. These results suggest that male faculty have a higher level of 'industry-based social capital'. In their analysis of nationwide survey data from the mid-1990s, Buttel and Goldberger (2002) reported a statistically significant and slightly larger gender gap in private industry consulting among land-grant agricultural scientists. Crowe and Goldberger (2009) similarly found that female agricultural scientists have fewer ties to industry (in terms of consulting and financial support) compared to male scientists when controlling for individual- and discipline-level characteristics.

Table 3: Percentage Distributions for Human Capital Variables by Gender, U.S. Land-Grant Agricultural Scientists, 2005

	Men	Women	Chi-Square
Ph.D. from Land-Grant University			
Yes	85.8	78.3	
No	14.2	21.7	
Total	100.0	100.0	6.108 *
Ph.D. from Top 10 Land-Grant University			
Yes	39.0	37.2	
No	61.0	62.8	
Total	100.0	100.0	.202
Postdoctoral Academic Experience			
Yes	33.8	38.3	
No	66.2	61.7	
Total	100.0	100.0	1.290
Post-Ph.D. Non-Academic Employment			
Yes	22.6	24.6	
No	77.4	75.4	
Total	100.0	100.0	.321
Farm Background			
Yes	18.2	6.7	
No	81.8	93.3	
Total	100.0	100.0	14.193 ***

* p ≤ .05; ** p ≤ .01; *** p ≤ .001 (Pearson chi-square test)

Table 4 reports means for our means of scientific production variables. We do not find a statistically significant gender difference in annual research program budgets. Moreover, we find no significant gender differences in the percentage of total funding from all but one of the listed funding sources. The only statistically significant gender difference is in private industry funding. On average, men receive 10.7% of their research funding from private industry, while women receive only 7.5% from industry sources. Buttel and Goldberger (2002) also found significant gender differences in private industry funding among land-grant agricultural scientists. In line with our earlier finding for industry consulting, male scientists appear to be more ‘connected’ to private industry compared to female scientists. In terms of employees, we find no major difference in the number of post-docs and technicians employed by male and female scientists. However, we do find a statistically significant gender difference in the number of graduate students. Interestingly, female faculty have *more* graduate student employees compared to their male colleagues.

Table 4. Means of Scientific Production Variables by Gender, U.S. Land-Grant Agricultural Scientists, 2005

	Men	Women	
Annual Research Program Budget ($)	151,075	157,061	
Funding Sources (% of Total Funding)			
Experiment Station funds	14.7	12.8	
Funds from own university/college	10.6	14.2	
USDA grants and cooperative agreements	21.7	20.3	
National Science Foundation	6.7	8.5	
National Institutes of Health	4.0	6.9	
Other federal government agencies	9.3	9.0	
State government agencies	8.9	7.4	
Commodity organizations	7.0	5.3	
Foundations	4.2	4.9	
Private industry	10.7	7.5	*
Other	2.2	3.2	
Total	100.0	100.0	
Number of Employees			
Graduate students	2.34	2.72	*
Postdoctoral fellows	.44	.43	
Technicians	.99	.83	
Actual Conditions of Employment (% of Total Time)			
Research	45.8	44.4	
Teaching	30.1	32.2	
Outreach	12.6	11.2	
Administration	9.5	9.3	
Other	2.0	2.9	
Total	100.0	100.0	
Research Orientation (% of Total Research Time)			
Basic research	35.7	37.3	
Applied research	55.8	57.3	
Development research	8.5	5.4	***
Total	100.0	100.0	
Research Tasks (% of Total Research Time)			
Research grant proposal preparation	18.5	23.5	***
Administration of current grants	20.7	19.2	
Actual research work	60.8	57.3	
Total	100.0	100.0	
Hours Worked per Week	54.0	57.1	***

* p ≤ .05; ** p ≤ .01; *** p ≤ .001 (two-tailed *t*-test)

Table 4 also presents *t*-test results for various time allocation variables. Unlike previous research (see literature review in Toutkoushian, 1999), we find no statistically significant gender differences in the percentage of total time devoted to research, teaching, outreach, and administration. In addition, our findings suggest that male and female agricultural scientists devote comparable portions of their time to basic research, applied research, grant administration, and actual research work. The only statistically significant gender differences relate to development research, grant proposal preparation, and hours worked per week. Male agricultural scientists devote a greater percentage of their research time to development research, defined in the survey as 'the production of useful materials, devices, and methods intended for commercial purposes', compared to female scientists. Women spend almost a quarter of their research time preparing grant proposals, while men spend less than a fifth of their time in the same activity. Women on average also work three more hours per week than their male counterparts. These results suggest that women faculty, perhaps because they are not taken seriously by male colleagues or face other forms of gender discrimination, must work harder to eventually receive the same recognition and promotion as men.

Table 5. Means for Number of Publications and Formal Presentations by Gender, U.S. Land-Grant Agricultural Scientists, 2005

	Men	Women	
Number of Publications (over 5-year period)			
Journal articles	12.58	11.10	
Sole or jointly authored books	.19	.16	
Edited books	.19	.11	*
Book chapters	1.92	1.71	
Abstracts	11.87	12.45	
Bulletins / Reports	8.82	6.07	*
Number of Formal Presentations (over 1-year period) to:			
Own department	1.05	.88	
Own university (outside own department)	.88	1.00	
Other universities	1.36	1.41	
Academic conferences	3.32	4.04	
Farmers or farm organizations	2.84	1.43	***
Cooperative Extension Service staff	1.11	.87	
Commodity groups	1.27	.87	
Non-profit or citizens groups	.82	1.24	
Private industry	1.20	.60	***

* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$ (two-tailed *t*-test)

Table 5 reports means for male and female agricultural scientists for the number of publications and formal presentations. Although there does not appear to be a gender gap for most types of publications and presentations, we find a few statistically significant gender differences. Female respondents published fewer edited books and bulletins/reports compared to male respondents. Moreover, women gave fewer presentations to farmer groups and private industry representatives compared to men. Given our earlier findings for farm background, industry consulting, and industry support, it is not surprising that women present less often to farmer groups and private industry.

Chi-square and *t*-test results (available from the authors) for our indicators of research commercialization indicate no statistically significant gender differences. Male and female scientists were equally likely to have engaged in patenting activities, marketed a product, and established a start-up company during 2000-2004. Despite these findings, male and female have significantly different expectations for their roles in the development of new technologies in the future. Survey respondents were asked the following question: 'Do you expect to contribute directly or indirectly to developing new technologies that will be used in the agriculture, food, fiber, or other private industries within the next 10 years?'. Survey results indicate that nearly 75% of men and 61% of women responded 'yes' to this question (Chi-square = 13.690, $p \leq .001$).

DISCUSSION

Gender inequality in the agricultural sciences in U.S. land-grant colleges of agriculture has not been studied to the same degree as gender inequality in other branches of academia, such as the social sciences, engineering, and the physical, biological and mathematical sciences (Allison and Long, 1990; Fox, 1995; Long, 2001; Xie and Shauman, 2003). Because of their public orientation and commitment to serving the needs of a diversity of agricultural and food system participants (including farmers, consumers, and other rural community members), colleges of agriculture offer scientists an academic environment distinct from other institutional settings. The goals and institutional structures of the agricultural sciences are qualitatively different from other sciences (Busch and Lacy, 1983). Moreover, expectations for tenure and promotion often include collaboration with non-academic partners, engagement in public outreach, extensive knowledge of agricultural production, and other factors not necessarily relevant for scientists in non-agricultural disciplines. Therefore, we should not assume that the experiences of faculty members, especially women, in agricultural fields of study are identical to the experiences of those in the non-agricultural sciences.

Relying on data from a nationwide survey of agricultural scientists, we asked two questions: (1) What degree of gender inequality exists in the agricultural sciences at land-grant universities? (2) Can gender inequality be attributed to differences in human capital, professional networking, means of scientific production, and/or research productivity? In sum, we found significant evidence of gender inequality in the agricultural sciences. Women were under-represented in all but one disciplinary category and were less likely than men to be appointed as full professors and be tenured. Moreover, female agricultural scientists on average had lower annual base and monthly salaries than male scientists.

After reviewing the women and science literature, we decided to explore four possible explanations for gender inequality in the agricultural sciences: human capital; professional networking; means of scientific production; and, research productivity. Our chi-square and *t*-test results offered limited support for the four explanations for gender inequality. No one explanation fit the agricultural sciences case above and beyond any other explanation. The only gender differences that might affect career outcomes were land-grant Ph.D. training (human capital); farm background (human capital); time devoted to development research (means of production); the number of edited books and bulletins/reports (research productivity); formal presentations to farmer groups (research productivity); and, scientists' linkages with private industry in terms of consulting (professional networking), funding (means of scientific production), and presentations (research productivity).

The mission-oriented land-grant universities, especially colleges of agriculture, are a unique component of U.S. higher education. Our analysis suggests that familiarity with both land-grant universities and the farming world may give male agricultural scientists an edge over their female counterparts. Specifically, male scientists are more likely to have grown up on a farm and received doctoral training at land-grant universities. In their academic positions, males are more likely to present to farmer groups and publish typically agriculture-related bulletins/reports. These significant gender differences in land-grant and farming experience may lead to different career outcomes for male and female agricultural scientists.

Another robust finding concerns gender differences in industry-based social capital. It appears that male agricultural scientists have significantly stronger ties to private industry when measured in terms of consulting for private firms, research support from industry, and formal presentations to industry groups. These results mirror findings from other studies of gender differences in university-industry relationships (see, e.g., Buttel and Goldberger, 2002; Corley and Gaughan, 2005; Whittington and Smith-Doerr, 2005; Crowe and Goldberger, 2009). Rising demands in academia to bring in private industry funding and to attend to the requirements of the market are at the core of university-industry relationships. Gender differences in industry-based social capital may contribute to gender gaps in promotions and earnings. Future research should investigate how the gender gap in university-industry relationships affects the reward system for agricultural scientists.

An especially surprising finding from our study is that female faculty in the agricultural sciences on average work more hours, employ more graduate students, and devote more time to research grant proposal preparation compared to their male colleagues. Moreover, our survey asked agricultural scientists about the importance (on a five-point scale) of different factors in motivating them to undertake their research programs. Two factors concerned commitment to science and society: 'potential contribution to scientific theory' and 'importance to society'. T-tests for mean scores of importance by gender indicate statistically significant gender differences for both of these items. Women are *more likely than men* to attribute importance to these factors in choosing research projects. These combined results for female faculty (i.e., working more hours, employing more graduate students, and exhibiting higher levels of commitment to science and society) should translate into rewards at least equal to those received by male faculty members.

LIMITATIONS

Despite the insights offered by this study, several limitations must be acknowledged. First, gender inequality in rank, tenure, and earnings could be causally related to the recent influx of junior-rank female scientists at land-grant colleges of agriculture. However, because of the relatively small number of senior-rank female professors in our sample, it is difficult to use multiple regression analysis to determine the effect of gender when controlling for multiple variables. Thus, we are unable to know for certain if gender differences in human capital, professional networking, means of scientific production, and research productivity are causally linked to lower proportions of female faculty in the agricultural sciences or gender differences in promotion and salary. After more female agricultural scientists earn tenure and rise in rank, we will be better positioned to use a multivariate approach to explore the relationship between various factors (human capital, professional networking, etc.) and gender inequality (e.g., pay differences).

Second, our gender inequality results could be due to the existence of an agricultural sciences 'glass ceiling' or the departure of female scientists from the land-grant system. Smith-Doerr (2004), for example, suggests that women may prefer less hierarchical organizational structures (e.g., private industry) over more hierarchical work environments (e.g., universities). However, our sample did not include scientists who had opted out of the land-grant system because of not receiving tenure, discouragement by colleagues or administrators, or other reasons. Additional research is needed to understand the relationship between organizational context and gender inequality in the agricultural sciences.

Third, our survey lacked questions about gender discrimination and gendered worldviews. Some women academics believe 'their gender is a roadblock to their careers' (NSF, 2003: 5). It follows that gender inequality in the agricultural sciences could reflect either overt or perceived discrimination against women. In land-grant colleges of agriculture, gender discrimination may be the result of male patriarchy, male-dominated academic culture, or the existence of an 'old boy's network' (see Marschke et al., 2007 for a review of 'privilege maintenance perspectives'). Women might also be less successful in the agricultural sciences compared to their male colleagues because, as some scholars argue, science is entirely masculine in its structure, epistemology, and methodology (Keller, 1985; Harding, 1986, 1991; Haraway, 1991; Longino, 1990). Future research should rely on qualitative interviews and related methods to compare female and male agricultural scientists' worldviews, 'situated knowledges' (Haraway 1991), and experiences with work-place gender discrimination.

CONCLUSION

It is unknown whether or when we will reach numerical parity of male and female faculty or eliminate the gender gaps in salaries and promotions in the agricultural sciences. In the meantime, it is essential to emphasize the important role women faculty play as mentors and role models for female students. It is equally important to increasingly draw on a diversity of perspectives to ask questions, interpret answers, and generate solutions to complex scientific and social problems. Science stands to benefit when men and women faculty bring different types of human capital, social capital, resources, work experiences, and worldviews to the academic table. The broadening of scientific inquiry is especially important in land-grant colleges of agriculture that not only contribute to scientific knowledge but also serve multiple constituencies.

ENDNOTES

[1] Means of Production: We refer here to in-hand resources that are essential in terms of producing scientific knowledge, for example funding, employees, time etc.

[2] U.S.-based four-year colleges provide education at the undergraduate level but do not offer graduate degrees.

[3] The '1862' land-grant universities refer to public institutions designated to receive the benefits of the first Morrill Act (1862). The second Morrill Act (1890) extended support to historically black institutions in the southern U.S. (known as the '1890' land grants). The '1994' land grants are Native American colleges and universities that were granted land-grant status under an Act of Congress in 1994.

[4] The Agricultural Research Service (ARS) is the research arm of the U.S. Department of Agriculture. USDA-ARS scientists are often housed in land-grant universities, but their responsibilities, reward structure, and compensation are different from state-based land-grant faculty.

[5] Commodity organizations represent specialized areas or voices within agriculture and the agribusiness industry. They can influence the direction of agricultural research through lobbying, funding of land-grant scientific research, and other activities.

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