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MORE THAN A PIPELINE PROBLEM: Labor Supply Constraints and Gender Stratification Across Academic Science Disciplines

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Employing a nationally representative sample of science faculty in U.S. colleges, we investigate 3 explanations for persisting differences in women's faculty representation across science fields even after adjusting for women's variable representation among doctoral recipients. First, we examine labor market factors: (a) differential growth rates and "critical mass" in the supply of women doctoral recipients, (b) growth or contraction in academic and nonacademic job opportunities, and (c) presence of foreign-born scholars. Second, we control for institutional explanations such as differential rates of faculty unionization and less receptivity to women at prestigious or research-oriented universities and fields that are "applied," "soft," or "nonlife" sciences. Third, gender role explanations are addressed by controlling for gender differences in work experience, work interruptions, and the prestige of doctoral credentials. After finding that none of these explanations account fully for distinctive patterns among science fields in the faculty gender composition, we discuss how they may reflect differences in academic "cultures."

KEY WORDS: women scientists; faculty women; gender inequity; doctoral labor supply; academic cultures.

The last quarter century has witnessed major shifts in the gender composition of doctoral recipients, but much slower change in the heavily male realm of the professoriate. By the late 1980s, women earned 43% of all doctoral degrees awarded in the United States but still accounted for only about a quarter of the full-time college faculty and an even smaller percentage of the tenured faculty or those at the rank of full professor. Women with doctorates are about three times more likely than their male colleagues to be underemployed, either by working only part time or not at all (National Science Foundation, 1988, 1999; Thurgood and Weinman, 1991). Female science faculty—the focus of our

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study—also tend to be highly segregated into relatively few fields. As of 1995, 84% of female scientists and engineers in academia were concentrated in three areas: life sciences, social sciences and psychology, with only 11% in the physical sciences and engineering (National Science Foundation, 1998). Among the prevailing explanations for the persisting "gender gap" in faculty representation are those that stress gender differences in education and family obligations (Astin and Davis, 1985; Hamovitch and Morgenstern, 1977); resulting geographic constraints on women's professional careers (Marwell, Rosenfeld, and Spilerman, 1979); gender differences in career goals, specializations, research subjects, and preferences for academic teaching, academic research or nonacademic employment (Fox and Stephan, 1996; Sonnert and Holton, 1995); gender discrimination promoted or protected by organizational and departmental structures in academia (Kulis, 1998; Perrucci, 1986; Szafran, 1984); and the influence of political constituencies external to academia (Salancik, 1979). This study focuses on another leading explanation for women's poor representation on college science faculties—the labor supply of women with doctoral degrees in various science fields.

Academic studies of the faculty gender gap and major government reports frequently have employed the metaphor of an inadequate training "pipeline," particularly in the sciences, math, and engineering (Ehrenberg, 1991; Justus, Freitag, and Parker, 1987; National Academy of Sciences, 1983; National Science Foundation, 1990; Pearson and Fechter, 1994; Tack and Patitu, 1987; White, 1989). Professional scientists' associations have joined with federal and state agencies to develop interventions to boost women's presence at all important junctures in the training pipeline, from grade school to graduate school and beyond. A common rationale for these efforts is the claim that a succession of institutional forces deflects women from successful primary and secondary school, undergraduate, graduate, and faculty experiences in the sciences. These obstacles may influence women's decisions to pursue baccalaureate and advanced degrees, as well as choices of specialties, graduate schools, postdoctorates, and type of employment (academic, government, industry). The pipeline metaphor conveys two possible aspects to the problem of women's underrepresentation in science: the importance of increasing the volume of the "flow" of women at previous stages and preventing "leakage" down the line.

MORE THAN A PIPELINE PROBLEM?

The pipeline metaphor assumes that an enlarged female doctoral labor pool (more flow) will expand the female professoriate. But the expanding female doctorate supply is unevenly distributed. Half of all doctorates awarded to women in the 1980s were in education, and women with science doctorates were concentrated in biology and psychology. There is also the problem of leakage in the pipeline metaphor that may counteract improvement in flow.

Between the early 1970s and late 1980s, women's share of new doctorates grew absolutely and proportionally in most fields, expanding the labor supply for faculty positions. In some science disciplines (psychology, anthropology), women made major inroads into graduate training programs, even to the point of virtual parity with men. Yet between 1977 and 1985, women's share of new doctoral degrees rose three times faster than increases in the rate at which they were hired for faculty jobs (Ehrenberg, 1991). Women's increasing representation in the faculty labor supply vastly outstripped their resulting representation among faculty. What was the cause of this leakage?

The link between women's representation among doctoral recipients and faculty is neither simple nor necessarily direct. It may be mediated by at least three dynamics, only one of which is the focus of this article. Women's presence in doctoral pools may be salient to gender inequities in faculty recruitment because it shapes disciplinary and organizational culture, because it affects perceptions of the comparable worth of scholarly work in different fields, or because it shapes labor availability and labor scarcity. Each of these dynamics poses different kinds of barriers to gender equity. The first posits problems for women in overcoming tokenism and powerlessness in unfriendly disciplinary and organizational cultures. The second emphasizes the devaluation of feminized occupations and potential threats, financial and otherwise, which parity may represent for men. We consider these two explanations in discussing our findings,[1] but this article focuses on the third set of dynamics: whether and how differences among science fields in the incorporation of women were a reflection of changes in the size and composition of the doctoral labor supply as well as the demand for labor. Our results also control for institutional and sex role explanations for differences in women's representation by field of science.

We focus on labor supply/demand measures to explore the limits of the pipeline explanation for understanding gender differences in faculty composition across the range of scientific fields. If women are differentially represented in scientific fields even after controlling for supply/demand factors, other explanations may be suggested by patterns of field-specific leakages of women between receipt of the doctorate and faculty employment. Perhaps interpretable patterns will emerge in the representation of women among the levels of faculty employment (nontenure, tenure-track, tenured), suggesting gendered academic career dynamics.

SUPPLY AND DEMAND EXPLANATIONS FOR FIELD-SPECIFIC FACULTY GENDER GAPS

The Female Doctoral Labor Supply

It seems obvious that the supply of female doctoral recipients influences markedly the gender composition of the faculty and accounts for much of the variation among fields in the recruitment and representation of faculty women.

Still, the way that fields and departments react to conditions of relative scarcity or abundance in the supply of doctoral women may not be uniform. Scarcities of women in the field may enhance an individual woman's chances of securing academic appointments and promotions, especially if increasing female representation is a high departmental or institutional priority. On the other hand, an abundant supply of doctoral women may support institutional and disciplinary norms that direct women into nontenure-track appointments. The way that supplies of female doctoral recipients shape faculty recruitment strategies may reflect particular academic "cultures" (Becher, 1989). Although women's representation in the doctoral training pipeline seems certain to affect their level of faculty representation, it is largely unknown whether the pattern and size of disciplinary differences in faculty gender composition persist after controlling for the gender-specific labor supply. Other aspects of labor supply and demand may account for any persisting differences.

Hiring Lags Following Growth Spurts in Women Doctoral Recipients

Differences among fields in women's faculty representation gap, relative to their supply of female doctorates, might result from recent dramatic increases in the production of women doctoral recipients in certain fields. Unprecedented large bursts of growth in the supply of doctoral-level women might presage, occasion, or follow major shifts in faculty hiring, but their incorporation onto faculties is unlikely to be immediate. Rapid massive changes in the gender composition of the doctoral labor pool may create a sizable apparent gender gap in hiring due to the lag between graduation and first faculty jobs. The length of this interval may vary from field to field due to variations in demand for new faculty, but a substantial degree of women's faculty underrepresentation can be attributed to inevitable "demographic inertia" between the new cohorts of increasingly female doctoral recipients and older heavily male tenured faculties (Hargens and Long, 2002).

Attaining "Critical Mass"

Women's historically acute underrepresentation in some science fields may have cultural and structural implications beyond the numerical constraints it has imposed on their availability for faculty jobs. Kanter (1977) advanced the theory that representation at token levels is a complex liability for women's employment opportunities and predicted a gradual increase in women's power and efficacy as their proportional representation improved. In fields that produce proportionally few female doctoral recipients, the constraints on women's influence within the profession, within colleges, and within departments can be compounded by small numbers of potential and actual women colleagues. According to this view, failure to achieve a "critical mass" of women in the field (over 15%) fuels stereotyping of female colleagues, stifles the development of women's professional networks, and impedes institutional change, thereby compromising women's chances of unbiased evaluations in recruitment, promotion, and tenure decisions (Etzkowitz, Kemelgor, Neuschatz, and Uzzi, 1994; Tolbert, 1986). Following this argument, fields in which women doctoral recipients reach critical mass levels should have better representation of women faculty, even controlling for the female doctoral labor supply.

Growth and Contraction in Doctoral Production

Differences among fields in women's faculty representation may also reflect the absolute size of the doctoral labor supply and its rate of growth or contraction. Fields with larger and growing doctoral pools present employers with a greater range of expertise and local availability of potential candidates for faculty jobs, thus increasing competition. This may affect women's faculty representation, because a large supply of doctoral recipients might exceed demand for their services. This said, it does appear that women have had a stronger presence in larger fields of science and engineering, such as electrical engineering and computer science, than in smaller fields like aeronautical and mechanical engineering (National Science Foundation, 1988; Thurgood and Weinman, 1991).

Variations in Demand for Academic Labor

Fields also differ in the demand for faculty labor, which may account for disciplinary patterns in women's representation. Fields in higher demand might spur greater doctoral production in general, and of women specifically, increasing women's odds of being considered for, and securing, faculty jobs. Studies of occupational crowding show there is less opposition to the entrance of women in the workplace when jobs are plentiful and demand for labor is high (Baron and Newman, 1989), because it helps neutralize political resistance to women's presence. Unlike processes of normal turnover, an expanding pie allows women to be hired without compromising the numerical or proportional dominance of men. In downsized or stagnant settings, altering the gender composition is more threatening. Just as growing firms have been found to hire more women (Shepherd and Levin, 1973), women's faculty gains were most appreciable in rapidly growing disciplines. Rossiter (1978) found that women were better represented on college faculties in the early 20th century within fields at the extremes of the growth curve: in the fastest growing fields where less competition eased men's resistance and in stagnant or contracting fields where women were more likely to accept relatively undesirable positions. It has been suggested that women tend to make bigger gains in stagnant or contracting occupations, those with eroding work conditions and rewards, and those in which men are departing for more rewarding or prestigious occupations (Reskin and Roos, 1990). This has been offered as a partial explanation for the rapid "feminization" of certain social sciences and for generally worsening job conditions in academia, such as the growth in reliance on nontenure-track positions to meet instructional needs (Rosenblum and Rosenblum, 1990).

Even if departmental faculties expanded in every scholarly field, however, that does not guarantee that women or other new entrants into the labor market will get the jobs, or the most desirable ones. Expanding fields may simply enhance opportunities for those already circulating in the labor market. In addition, in growing fields, women's share of entry-level or nontenure-track appointments may increase without redressing gender gaps in tenure and promotion. Rosenblum and Rosenblum (1996) found that the proportion of new faculty appointments obtained by relatively young recipients shrank from 1977 through 1983. Since women's representation among science doctoral recipients increased sharply throughout this period, supply might easily have outstripped demand as women entered a labor market with fewer new faculty positions. Thus, gender gaps in faculty representation could remain largely uncorrected.

Nonacademic Employment Opportunities

Other facets of the labor force's composition in one's field of training are also likely to shape career options within each science field, possibly in different ways for men and women. For example, career choices might be influenced by the availability of nonacademic jobs within the field. There is a growing tendency among new doctoral recipients to seek and find employment outside academia, from around half in the mid-1970s to around two thirds by the late-1980s. This tendency can be explained, in part, as salary driven. Turner, Myers, and Cresswell (1999) found that faculty representation for ethnic minority scholars grew as faculty salaries increased and fell as private sector salaries increased. They concluded that the push to find nonacademic jobs due to low salaries inside academia was a stronger factor in minority faculty representation than the lure of lucrative private sector employment. Women with doctorates, however, have been most heavily concentrated in fields that offer fewer nonacademic employment options (education, humanities, life sciences, social sciences), while doctoral level men have predominated overwhelmingly in fields with the most nonacademic job opportunities and perhaps the most lucrative ones (physical sciences and engineering). A gender gap in employment plans appears even prior to receipt of the doctorate, with more women (46%) than men (36%) planning to enter academia after receiving the doctorate (Lomperis, 1990). We might then expect relatively better representation of women faculty in fields with numerous nonacademic job opportunities, as women are more likely than men to choose academic careers. But the academic labor market for female scientists has grown more slowly than the industrial or governmental sector. Between 1976 and 1986, the number of women scientists in industrial jobs expanded by 17%, but only by 10% in the academic sector (National Science Foundation, 1988). Thus the availability of nonacademic job opportunities might influence the odds that women doctoral recipients find academic jobs, perhaps in ways that account for disciplinary differences in women's faculty representation.

Participation of Foreign-Born Scholars

Women's expanding share of doctoral labor pools also coincided with sharp increases in the proportion of doctoral scientists born abroad. Some attribute the growth in U.S. doctorates awarded to noncitizens to a labor shortage in science and engineering in the mid-1970s (Vetter, 1992). With little unemployment and high salaries among those holding baccalaureate degrees in the physical sciences and engineering, fewer U.S.-born students entered graduate school, and universities turned increasingly to foreign students. By 1990, about one third of all doctorates awarded in the United States were earned by non-U.S. citizens, comprising around half or more of those earning doctorates in engineering, math, and computer science (Vetter, 1992). The potential gender implications here are numerous. Women are less well represented among foreign-born graduate students than among the U.S.-born doctoral candidates. In fields with many foreign-born scholars, women may face disadvantages in graduate school and faculty jobs due to the heavy numerical predominance of men among the foreign born, such as contending with more traditional ideas about gender roles at work. In addition, because foreign-born workers can be limited from entering other employment sectors, such as defense, their presence may increase the level of competition for academic jobs in fields where they are relatively numerous. This line of argument suggests that women would have more difficulty finding academic employment in fields with proportionally more non-U.S.-born doctoral recipients.

GENDER AND SCIENCE DOMAINS

When examining the gender composition of the disciplines of science, the lines demarcating fields are often fuzzy. Gender contrasts can be heightened or obscured depending on how the disciplines are categorized. This study generally observes traditional boundaries (see Table 1), although for some labor supply predictors we employ sub-discipline breakdowns, as explained later. There are substantive reasons, however, to investigate disciplinary differences according to schemes that collapse fields into those that are "hard" versus "soft," "life"

TABLE 1. Science Fields and Subfields (of doctoral degree) for SDR Sample Respondents[a]

Field [*N*—unweighted]	Subfield [unweighted *N*]
Biology [2219]	Biochemistry [243], Botany [187], Cell/Molecular [343], Ecology [103], Genetics [105], Microbiology/ Bacteriology [229], Nutrition [106], Zoology [345], Other [558]
Physics/Astronomy [803]	Astronomy [153], Atomic, Nuclear, and Plasma [203], Solid State [129], Other [318]
Chemistry [1018]	Analytic [105], Biological [157], Inorganic [137], Organic [214], Physical [159], Other [246]
Earth/Environmental Science [856]	Atmospheric [87], Geology [520], Oceanography [143], Other [106]
Mathematics [1319]	Algebra [141], Analytic [181], Applied [135], Statistics [191], Other [671]
Computer Science [580]	Computer Information Science [98], Other Computer Science [482]
Engineering [1286]	Aeronautical [53], Chemical [138], Civil [155], Electrical [227], Materials [80], Mechanical [184], Other [449]
Agriculture [833]	Agricultural Economics [175], Animal Agriculture [138], Fish and Wetlands [33], Forestry [64], Soil Science [66], Plant Agriculture [299], Other [58]
Health Science [980]	Epidemiology and Public Health [95], Nursing [304], Speech Pathology [190], Veterinary [104], Other [287]
Economics [405]	
Political Science [335]	
Psychology [1162]	Clinical [247], Cognitive [64], Counseling [87], Developmental [131], Experimental [144], Industrial Organization [49], Physiological [74], School and Educational [87], Social [111], Other [168]
Sociology [391]	
Anthropology/Archeology [216]	
Applied Social Science [828]	Communications [231], Public Affairs, Criminology and Urban Studies [147], Demography and Area Studies [134], Other [316]

Note: For each SDR respondent, the applicable subfield breakdowns are used in the assignment of three variables estimating the female doctoral labor supply, the change in total doctoral production, nonacademic employment, and percentage of non–U.S.-born doctoral recipients.

[a]Total *N* = 13,231.

versus "non-life," and "applied" versus "pure" (Biglan, 1973). For example, the fields of science may differ in receptivity to women along a hard science—soft science axis because of variations in consensus about core theories and methods. Well-established paradigms in the hard sciences may help ensure that scholarly achievements can be evaluated without bias (Hargens and Hagstrom, 1982). This is one explanation for findings that editorial decisions and external grant awards are influenced by more particularistic bias in the social sciences than in the physical sciences (Beyer, 1978; Yoels, 1974). Lack of conformity with prevailing theoretical orientations within their discipline may be particularly problematic for women, especially in disciplines without central paradigms (Bernard, 1975; Reskin, 1988). These particularistic biases may be especially detrimental to women scientists' careers in the social sciences, influencing graduate student mentorship, faculty recruitment, and promotion. If these biases do operate more to women's than to men's disadvantage (due to a gap in informal training and networking, and due to in-group bias), we would expect to find that, controlling for the doctoral labor supply, women would be less well represented in social science ("soft") than natural science ("hard") fields.

There are also gender ramifications to distinctions sometimes made between life and non-life science fields (Biglan, 1973). As noted, women earn far more doctorates in life sciences like psychology and biology than in nonlife sciences like engineering. Perhaps the same forces of gender socialization that direct women toward careers in education and the humanities rather than the sciences also influence their pathways into the various branches of science. The life sciences may be viewed as more appropriate career choices for women because they relate clearly to nurturing human pursuits that are consistent with traditional gender ideals for women. Women may have better access to careers in the life sciences because they depend less on securing the military-industrial grants common in nonlife scientific research. Other factors held constant, we would thus expect better representation for women faculty in the life than nonlife sciences.

The notion that some scholarly fields are more "applied" and others are "pure," pursuits has numerous implications for the gender composition of faculty. Many professions historically dominated by men—business, engineering, law, and medicine—are viewed as applied. This may reflect a cultural preference for applied over pure knowledge pursuits, rooted in a sense that the value systems of these fields correspond to those of highly influential industrial and military sources of research funding (Biglan, 1973). In addition, an applied focus may indirectly affect the nature of administrative control in academia and the degree to which gender discrimination escapes scrutiny or goes unchecked. These arguments lead to the expectation that women would face less severe obstacles to securing faculty employment in pure than in applied fields.
After examining differences among science disciplines separated along the

traditional lines, we collapse them to assess how well these three science axes—pure versus applied, life versus nonlife, and hard versus soft—account for the gender composition of the science faculty.

INSTITUTIONAL FACTORS IN THE GENDER COMPOSITION OF SCIENCE FACULTIES

The previous discussion presents a number of ideas about how administrative structures and processes differ across types of institutions and departments in ways that may impact the incorporation of women faculty. Although it is not the key focus of our study, we feel that some of these factors have to be controlled when assessing the impact of the central variables under consideration—labor supply and discipline. One factor distinguishing fields is the likelihood of securing large external research grants, which Clark (1987) suggests, buy a degree of insulation from top administrative control and scrutiny of personnel matters. Similarly, academic departments with substantial external funding, extensive opportunities for applied professional practice, or high levels of prestige may increase the power of the department chairperson over personnel matters and diminish the control of higher administration. These situations are also likely to be found in heavily research-oriented institutions rather than in teaching-oriented liberal arts colleges. Although having an independent chairperson may at times operate to women's advantage, it also increases the chairperson's ability to exercise biases against women in recruitment and promotion. The institutional contexts where chairs might wield more individual authority—prestigious, research-oriented departments in fields where large grants are highly prized and common—are those where women faculty are especially scarce (Cole, 1979; Kulis, 1998). Faculty unionization may counterbalance the unchecked discretion of the chair by formalizing hiring, promotion, seniority, and remuneration processes, and by providing an avenue for appeal in instances of felt discrimination (Baron and Newman, 1990; Cohen and Pfeffer, 1986). To account for the impact of these factors in at least a general way, our analysis introduces controls for institution type, using the Carnegie classification, for departmental prestige, and for faculty unionization.

HUMAN CAPITAL INVESTMENTS AND FAMILY CONSTRAINTS FOR WOMEN FACULTY

Finally, among the competing explanations for gender differences in academia are strong arguments for individual-level factors that we incorporate into our analysis as control variables. Proponents of human capital theory argue that women, more than men, seek educational and work settings that provide flexibility in meeting family, childbearing, and childrearing demands (Becker, 1971).

This decisionmaking calculus might draw men and women to different job opportunities and different fields inside and outside of academia. Some fields may be characterized by a “male model” of academic success, involving total time commitment to work and aggressive, competitive relations with peers, making marriage and motherhood seem incompatible with an academic career (Etzkowitz, Kemelgor, Neuschatz, and Uzzi, 1992). In some fields, the growing need to accept postdoctoral fellowships to launch a successful research career not only postpones entry into a permanent academic job but may mean that women have to choose between delaying childbearing for many years or undertaking many more years of preparation for a career while simultaneously raising small children. One proxy for the pull of such family obligations is work interruptions, a global measure of child and other family responsibilities that may draw women, more than men, away from research and successful academic careers. Women’s postdoctoral work experience could also be a factor in the faculty representation gap; if family considerations lead women to have relatively less work experience, they may be less competitive in a struggle for faculty positions. If this work experience gap varies among scientific fields, then we would expect the faculty gender gap in representation to vary accordingly.

It is also possible that male and female scientists receive doctoral credentials from more or less prestigious universities. The prestige of an academic’s doctoral-granting university has been shown to have a substantial effect on the attainment of first faculty position (McGinnis and Long, 1988), but this effect varies substantially by scientific field (Youn and Zelterman, 1988). If women have less prestigious degrees than men, on average, and this prestige gap varies among fields, then this may at least partially explain disciplinary differences in the faculty gender gap.

STUDY OBJECTIVES

The specific purposes of this study can now be summarized as following a strategy of “sophisticated residualism” (Cole, 1979), that is, assessing or ruling out a succession of explanations that may account for variations across fields in the representation of women among college science faculty. The factors we examine are based on possible labor market, institutional, and human capital forces that may shape academic careers differently for men and women. After these factors are accounted for, any unexplained variance in women’s faculty representation may be attributed to factors that we have not operationalized explicitly, including overt discrimination, unintentional bias, and inhospitable academic cultures.

The point of departure for our analysis is the pattern of differences in faculty gender composition among the various branches of science. We first investigate the degree to which differences among fields are a product of the (a) doctoral labor supply, that is, variations in the gender composition of doctoral recipients in specific fields and subfields, and how differences among fields change after controlling for the female doctoral labor supply. We then test whether the remaining differences among fields in women's faculty representation can be attributed to: (b) failure to attain a critical mass of women among the field's doctoral recipients; (c) sharp spikes in women's presence among graduate students in the field; (d) growth or contraction in the number of doctorates being granted in the field; (e) increasing or contracting demand for faculty in the field; (f) availability of nonacademic employment for doctoral recipients in the field; (g) participation of foreign born scholars in the field; (h) gender differences in type of institutional employer (e.g., unionized, prestigious, research versus teaching oriented); and (i) individual-level gender differences in the prestige of doctoral credentials, work experience, and work interruptions. The analysis proceeds then to a comparison of how these explanations account for women's faculty representation in three employment sectors—the secondary labor market of nontenure-track jobs, the tenure-track jobs that are entry into more secure employment, and the heavily male realm of tenured positions—as well as comparisons across different faculty cohorts. Finally, we examine the persisting pattern of differences among fields in the faculty gender composition for signs that they line up along pure/applied, hard/soft, or nonlife/life science axes.

DATA AND METHODOLOGY

The data for this study were produced by merging questionnaire responses from college faculty in the United States with characteristics of their scholarly fields and the institutions employing them. Individual respondents were drawn from the 1989 Survey of Doctoral Recipients (SDR). This representative survey of the doctoral-level labor force in the United States is conducted biennially by the National Research Council (NRC) for the National Science Foundation and other federal agencies. The SDR contains profiles of the academic careers of doctorate holders, with large oversamples of women from all fields. This article employs an SDR subsample consisting only of faculty members in 4-year colleges or universities in science or science-related fields. Although the SDR is not deliberately stratified by type of postsecondary employer, the respondents worked in every type of baccalaureate-granting institution in the United States. The 13,231 faculty members in the sample (before attrition due to missing values) came from a large cross-section of institutions, encompassing over three quarters (1,071) of all 4-year institutions.

The analysis utilizes several variables from the SDR data: gender, field and subfield of doctoral training, the institution granting the recipient the doctorate, the year the doctorate was awarded, the respondent's current tenure status, years of work experience, and number of career interruptions since receiving the doctorate. The respondents were grouped into 15 fields of doctoral training, and for some measures of labor supply and demand, they were further divided into subfields (Table 1). We matched the SDR data to several measures of the doctoral labor supply in the respondent's field or subfield of training, all calculated separately from the annual Survey of Earned Doctorates (SED), which is compiled annually by the National Research Council from questionnaires given to doctoral recipients by their degree-granting institutions. The first doctoral labor supply measure is the percentage female among all those granted doctoral degrees in the respondent's field or subfield between 1976 and 1988. The second is the change in women's level of representation among doctoral recipients in the field or subfield (percentage female) from the beginning to the end of that period. The third is the percentage change from 1976 to 1988 in number of doctorates awarded to men and women combined in the field or subfield.

These doctoral supply measures were based on the 12 years prior to the faculty interviews to account for yearly fluctuations, particularly in subfields where women are scarce and because the measure should ideally include those who formed the pool for entry-level faculty jobs and for tenured positions requiring a substantial lapse of time on the job. Still, it is important to examine our results separately for tenured and untenured faculty and for different doctoral cohorts because the 12-year estimates of the doctoral labor supply are arguably more descriptive of the labor market conditions in force for faculty entering academia after 1975 than before that time. Because women's representation among graduate students and faculty differs substantially among the sub-branches of some disciplines, for example in clinical psychology versus experimental psychology and in botany versus zoology, subfield measures of the doctoral labor supply were calculated for those in fields with discernable and reported subdivisions (see Table 1 for the subfield breakdowns). Each of these disciplines was divided into its specialty branches when labor supply measures were used in analysis. Except for psychology, faculty in the social sciences were not broken down by subfield because these breakdowns are not reported in the SED data, no doubt reflecting less well-established subfield boundaries. Faculty working in the fields we have grouped together as applied social science fields were assigned the gender composition for doctoral recipients in their own field (communications, demography, etc.). Another reason for employing these subfield breakdowns is that, because so much of the difference across fields in women's faculty representation can be attributed to corresponding variations in their share of doctorates earned in the field, it is difficult to avoid multicollinearity in explaining disciplinary differences in the faculty gender composition while simultaneously controlling for the doctoral gender composition. We are able to do so only by measuring the female doctoral labor supply within subfields in multivariate analyses.

We created a measure of nonacademic employment opportunity from published estimates (National Science Foundation, 1988) of the percentage of doctoral level U.S. workers in various fields or subfields who worked outside academia near the time that respondents were surveyed and matched these to our SDR faculty respondents in the same fields and subfields. Using the 1989 SDR data, we also calculated the percentage of faculty in each field and subfield who were born outside the United States, and matched the appropriate figure to individual respondents. The SDR faculty data were also matched to characteristics of their employing institutions and departments. These included dummy variables for institutional type: Carnegie (1987) classification as Research I or Research II, other doctoral-granting institutions, comprehensive universities granting no higher than the master's, and baccalaureate institutions (the reference category). Another dummy variable indicated whether faculty in the institution were unionized (Douglas, 1990). A final employer characteristic at the departmental level measured demand for labor within the respondent's field: the percentage change (growth or contraction) over a decade (1975 to 1985) in the number of faculty employed in the respondent's department (from the NSF Survey of Science and Engineering Personnel Employed at Universities and Colleges). A measure of the prestige of the respondent's doctoral credentials was also included, based on the National Research Council's global rating of the scholarly reputation of the department from which the respondent earned the doctorate (Jones, Lindzey, and Coggeshall, 1982).

When properly weighted, the data comprise a representative sample of 4-year college faculty in 1989 holding doctorates in science, math, and engineering. Unless otherwise indicated, all results have been weighted using normalized weights that maintain the actual sample size.

In multivariate analyses employing hierarchical logistic regression, we use field of training, doctoral labor supply, organizational, and individual demographic characteristics to predict the odds that the occupants of faculty positions were female. All multivariate equations were free of multicollinearity biases as indicated by low variance inflation factor scores for all predictors. The unit of analysis in these logistic regression analyses is the individual level. We employ independent variables that describe scholarly fields and organizational level phenomena to make predictions at the individual level for both theoretical and methodological reasons. First, our key hypotheses that doctoral labor supply and demand affect faculty gender composition assume that factors at the level of scholarly fields influence particular faculty appointments and retention, thereby shaping the overall gender composition. Second, we avoid methodological complications by measuring all but one (percent non–U.S.-born in the field) of the organizational variables as global characteristics rather than as contextual measures aggregated from individual level data. Third, by making predictions about specific faculty positions rather than the faculty gender composition at the institutional or departmental level, we are able to control for the female doctoral labor supply in the particular field of the appointment.

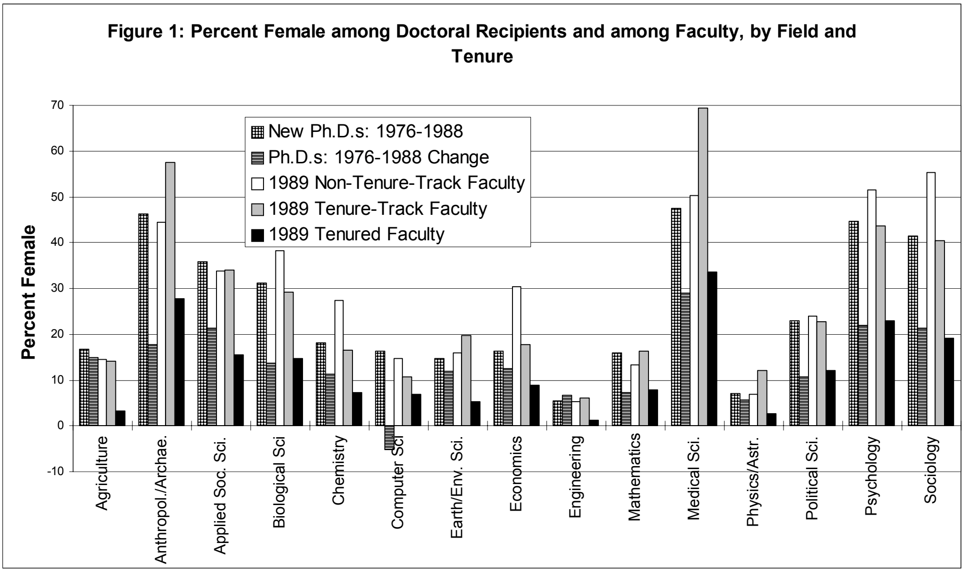
RESULTS

Figure 1 compares women's representation among doctoral recipients and faculty members across scholarly fields at the aggregate level. Two aspects of women's presence in the doctoral pool in each field are represented: percentage female among all those receiving doctorates from 1976 to 1988; and the change in women's share of doctoral recipients. The first measure indicates women's level of representation in doctoral pools, while the second (percentage female in 1988 minus percentage female in 1976) gauges the degree to which women's representation increased over this period. The last three bars for each field show women's proportional representation among faculty in nontenure-track, tenuretrack, and tenured positions.

Several trends are noteworthy. First, there was great variability across fields at the end of the 1980s in women's level of representation among doctoral recipients and faculty: women accounted for only around 5% of doctoral engineers but approached parity with men in anthropology, health sciences, psychology, and sociology. Women's presence lined up roughly along a physical—life—social science continuum, with better representation at the latter end. Women's presence varied inversely with conceptions of the degree to which the field is a hard science. But within the three major groups of science fields there were further distinctions. Women were rarest in an applied physical science—engineering—and less well represented in physics and astronomy than in chemistry or earth sciences. Among the social sciences, women were much less well represented in economics and political science. Biological sciences could be seen as occupying a middle ground, but the other life sciences were at opposite extremes, with women acutely underrepresented in agriculture but at near parity in health sciences.

Second, the fields also differed greatly in the extent to which women's presence in the field reflected relatively recent gains among doctoral recipients. Nearly all of women's small share of doctoral recipients in agriculture, physics/astronomy, earth/environmental sciences and engineering can be attributed to gains occurring after 1976. The more recent arrival of women in these fields thus left little time for promotion to tenured positions by 1989. In other fields, particularly the social sciences, there was an even larger increase in women's share of doctoral recipients from 1976 to 1988, but that increase accounted for less than half of women's overall share of doctorates throughout the period. In these fields women already earned an appreciable share of doctorates before 1976, providing a labor supply for faculty who might have progressed to tenure

FIG. 1. Percent female among doctoral recipients and among faculty, by field and tenure.



and full professor rank. Computer science was distinctive as the only field where women's representation among doctoral recipients actually declined after 1976.

Third, there was some correspondence between women's representation in doctoral and faculty pools, but these similarities vary considerably by tenure status, and more so in the social than in the natural sciences. Three distinctive patterns emerge. One typified fields where women occupied a similar proportion of the doctoral labor supply and all junior faculty positions (nontenure-track and tenure-track), sometimes at sparse levels below the critical mass of 15% (agriculture, engineering, mathematics) but in other instances at much higher levels of participation (applied social science, political science). Equally common were fields where women's share of tenure-track faculty positions matched closely their availability in the doctoral labor supply while being overrepresented among nontenure-track faculty (biology, chemistry, economics, psychology, and sociology). Here women's share of the most insecure and poorly paid faculty jobs exceeded the female doctoral labor supply by 5% to 14%. Another pattern applied where women were somewhat better represented among tenuretrack faculty than in the overall doctoral pool to a sizeable (anthropology/archeology, health sciences) or modest (earth/environmental sciences, physics/astronomy) degree. Computer science was unique, suggesting a substantial attrition in women's representation at each step of an academic career.

The most striking consistency in Figure 1 is that women's share of tenured positions in all science fields fell well short of their representation in the doctoral labor pool. Although some of this tenure gap may be the result of inadequate time in rank for female newcomers to progress to a tenure decision, it also reflected the fact that most of the faculty with tenure in 1989 had enjoyed that status for over 12 years, and these more senior faculty were overwhelmingly men.[2] It is interesting to note that women's share of tenured jobs corresponded roughly to their level of representation among doctoral recipients prior to 1976, that is, to the female share of the doctoral pool that is not attributable to growth occurring between 1976 and 1988.

Although these aggregated data do not definitively link doctoral supply to faculty representation, the correspondences add up to a compelling pattern. The sizable differences among science disciplines in the female labor supply suggest varying degrees of constraint on women's faculty representation. These variations in labor supply must be controlled to investigate the extent to which women with the requisite training progress toward faculty positions.

Table 2 presents logistic regression estimates of the odds that women occupied particular faculty positions in specific departmental, institutional, and disciplinary contexts. First, dummy variables for scholarly field are entered as predictors, with biological sciences as the omitted reference category. The results for this first equation reproduce patterns found in Figure 1, showing that compared to biology, women were poorly represented in agriculture, engineering, the

TABLE 2. Logistic Regression Predicting Whether Faculty Position Is Held by a Woman (log odds)

	[1] B	[2] B	[3] B	[4] B	[5] B	[6] B
Physics/Astronomy	-1.766 ***	-0.712 ***	-0.709 ***	-0.725 ***	-0.721 ***	-0.643 **
Chemistry	-0.710 ***	-0.158	-0.169	-0.264	-0.255	-0.143
Earth/Environmental Science	-0.988 ***	-0.352 *	-0.366 *	-0.379 *	-0.377 *	-0.495 **
Mathematics	-0.977 ***	-0.413 ***	-0.434 **	-0.318	-0.324	-0.304
Computer Science	-0.912 ***	-0.388 *	-0.409 *	-0.468 *	-0.476 *	-0.536 **
Engineering	-2.332 ***	-1.239 ***	-1.228 ***	-1.372 ***	-1.357 ***	-1.272 ***
Agriculture	-1.361 ***	-0.754 ***	-0.707 ***	-0.702 ***	-0.699 ***	-0.692 ***
Health Science	1.079 ***	0.285 *	0.326 **	0.344 **	0.341 **	0.246 *
Economics	-0.699 ***	-0.068	-0.092	-0.042	-0.047	-0.155
Political Science	-0.497 ***	-0.214	-0.248	-0.150	-0.142	-0.236
Psychology	0.470 ***	-0.197 *	-0.118	-0.155	-0.154	-0.089
Sociology	0.293 **	-0.267 *	-0.199	-0.111	-0.111	-0.209
Anthropology/Archeology	0.623 ***	-0.168 ***	-0.131	-0.069	-0.074	-0.141
Applied Social Science	-0.044	-0.456 ***	-0.445 ***	-0.422 ***	-0.427 ***	-0.537 ***
% Female: 1976-1988 Ph.Ds.		0.048 ***	0.047 ***	0.047 ***	0.046 ***	0.042 ***
Female Ph.D.s 1976-1988 > 15%			0.097	0.130	0.135	0.218 *
Change in % Female Ph.Ds.			-0.009	-0.007	-0.007	-0.005
% Change in # of Ph.Ds.				0.001	0.001	-0.001
% Departmental Growth				0.001	0.001	0.000
% Outside Academe				0.004	0.004	0.003
% Not U.S. Born				0.004	0.005	-0.001
Faculty Unionized					0.169 *	0.282 ***
Research I,II						-0.139
Doctoral I,II						-0.309 **
Comprehensive I,II						-0.224 *
Departmental Prestige						-0.016
Doctoral Degree Prestige						0.022
Post Ph.D. Experience						-0.081 ***
Work Interruptions						0.079 *
Intercept	-1.255	-2.672	-2.621	-2.954	-2.988	-1.669
N	13188	13188	13177	13177	13177	13177
-2 Log Likelihood	10720.7	10384.8	10363.9	10358.2	10348.9	9646.2
d.f.	13173	13172	13159	13155	13154	13147
-2 Log Likelihood / d.f.	.814	.788	.788	.787	.787	.734
Pseudo R^2	.084	.107	.108	.108	.109	.155
Percent Correctly Predicted	57.2%	62.1%	61.9%	62.5%	62.7%	69.2%
P^2, (d.f.)	1161.8 *** (14)	1497.7 *** (15)	1500.7 *** (17)	1506.4 *** (21)	1515.7 *** (22)	2218.4 *** (29)
P^2 Improvement Over Prior Model		335.9 ***	20.9 ***	5.7	9.3 **	702.7 ***

physical sciences, math, computer science, economics and political science, but were better represented in psychology, sociology, anthropology/archeology, and especially in health sciences.

The second equation controls for disciplinary and subfield variations in women's presence in the doctoral labor supply: percentage female among all doctoral recipients in the faculty member's subfield or field between 1976 and 1988. Interpreting the coefficient for this variable through the delta-p transformation (Petersen, 1985), we find that a one percent larger share for women in the doctoral pool increased the predicted odds that women occupied faculty positions by slightly less than 1% (.0067). When the female doctoral supply is controlled in this way, the differences among fields in women's faculty representation become less pronounced, but they do not disappear entirely. The relative positions of some fields remains the same, with women faculty still least well represented in engineering, physics, and agriculture. The earth/environmental sciences, math, and computer science continue to have poorer representation of women faculty compared to biology. But the position of some social sciences relative to biology shifts: psychology, sociology, anthropology/archeology, and applied social sciences had significantly lower odds than biology of having women occupy their faculty position after controlling for their female doctoral supplies. Although by a smaller margin, the health sciences continued to stand out as having higher odds than biology that women will hold faculty jobs.

The continuing, although attenuated, differences among fields and their shuffled arrangement suggest that women's faculty representation did not merely reflect differences in the doctoral labor supply. Relative to their representation in doctoral pools, women's chances of occupying faculty lines were actually worse in some of the social sciences where women approached parity with men in earning doctorates than in the biological sciences. Using the pipeline metaphor, the marked variations in the degree to which women moved into faculty positions in proportion to their representation among doctoral recipients suggest there was less leakage as women moved from graduate school into faculty jobs within the health and biological sciences than in many other fields. In contrast, women in engineering, agriculture, and the physical sciences were much more severely under-represented in faculty jobs relative to their availability in the doctoral labor pool. Why would fields differ so markedly in the degree to which doctoral women were incorporated into college faculties? The remaining equations in Table 2 investigate possible reasons for this pattern.

The third equation adds two predictors that measure additional aspects of the female doctoral supply: women's achievement of critical mass and sharply expanding representation. The first of these is a dummy variable identifying science fields or subfields that granted more than 15% of their doctorates to women in the collective years between 1976 and 1988. The next predictor gauges the change in women's share of doctoral degrees in the field or subfield, specifically the number of percentage points that women's representation in doctoral pools grew or shrank between 1976 and 1988. Neither of these factors was a significant predictor of women's faculty presence, but their inclusion does slightly reduce the size of the coefficients for some social science fields such that they become nonsignificant.

The fourth equation controls for factors related to overall supply and demand for doctoral labor in different fields. One is the extent of growth or contraction in the number of doctorates awarded in the field or subfield to men and women combined, measured as the percentage change between 1976 and 1988. This was a period when doctoral production shrank in most science fields, often substantially, by almost half in political science and sociology, and by nearly a quarter in anthropology, economics, and physics/astronomy. Labor demand is controlled at the organizational level by the next predictor, which measures growth/contraction in the number of faculty in the respondent's department over the prior decade. The next two predictors model aspects of employment opportunity structures for doctoral recipients in different fields: the extent to which doctoral-level workers in the field typically work outside academia and the proportion of these workers born outside the United States. These four variables had no appreciable impact on the faculty gender composition, and they do not alter the distinctive pattern of differences among fields in women's faculty presence, apart from reducing the coefficient for mathematics to nonsignificance.

The fifth equation controls for whether the faculty respondent worked in a unionized setting, which produced appreciably higher odds of having women in faculty jobs. Again however, the pattern and magnitude of differences among fields remain largely unchanged.

The last equation controls for various characteristics of the employing institution and department and of the individual faculty member's career background. The first set of these predictors indicates that Doctoral and Comprehensive institutions had lower odds that women were in faculty positions than liberal arts colleges (the omitted reference category), but these odds were not significantly lower for Research I and Research II institutions. In a similar vein, departments with more prestigious scholarly reputations were not significantly less likely to have women in faculty positions than less prestigious departments.

The last three predictors adjust for possible gender differences at the individual level: in the prestige of the departments from which faculty received their doctoral degrees, in years of work experience beyond the doctorate, and in the number of career interruptions. These show that women faculty tended to have less work experience and more career interruptions than their male counterparts, but similarly prestigious doctoral credentials. Once again these predictors fail to change most of the patterns among fields in women's faculty representation as shown in the second equation. A new pattern emerging from the last equation is that the estimated effect of critical mass increases and becomes significant.

TABLE 3. Logistic Regression Predicting Whether Faculty Position Is Held by a Woman, by Tenure Status and Ph.D. Cohort

	Not Tenure Track	Tenure Track	Tenured	Ph.D. < 1970	Ph.D. In 1970s	Ph.D. In 1980s
	B	B	B	B	B	B
Physics/Astronomy	-0.989 **	0.011	-0.684 *	-0.845 *	-0.630	-0.512 *
Chemistry	-0.005	-0.066	-0.297	-0.096	-0.127	-0.153
Earth/Environmental Science	-0.558 *	0.130	-0.688 *	-1.430 *	-0.748 *	-0.129
Mathematics	-0.718	-0.031	-0.193	-0.314	-0.347	-0.434
Computer Science	-0.992 **	-0.502	-0.435	-0.539	-1.114 **	-0.192
Engineering	-1.240 **	-0.546	-1.729 ***	-2.484 **	-1.570 ***	-0.874 **
Agriculture	-0.627 *	-0.307	-0.970 **	-1.836 **	-1.306 ***	-0.231
Health Science	-0.254	0.695 *	0.163	-0.448	-0.062	0.738 ***
Economics	-0.293	-0.049	-0.112	-0.257	-0.115	-0.177
Political Science	-0.435	-0.083	-0.124	-0.711 *	-0.405	0.067
Psychology	-0.137	0.106	-0.209	-0.391	-0.105	0.118
Sociology	0.104	0.065	-0.372 *	-0.238	-0.254	-0.198
Anthropology/Archeology	-0.588	0.274	-0.050	-0.181	-0.344	-0.004
Applied Social Science	-0.747 **	-0.221	-0.508 **	-0.727 *	-0.765 ***	-0.325 *
% Female: 1976-1988 Ph.Ds.	0.040 ***	0.039 ***	0.046 ***	0.035 ***	0.052 ***	0.039 ***
Fem. Ph.Ds. 1976-1988 > 15%	0.193	0.149	0.223	0.296	0.226	0.176
Change in % Female Ph.Ds.	0.023	0.003	-0.015	-0.001	-0.028 **	0.010
% Change in # of Ph.Ds.	-0.002	0.001	-0.002	-0.002	-0.003 *	-0.001
% Departmental Growth	-0.001	0.000	0.001	-0.000	0.001 *	0.000
% Outside Academe	0.003	-0.002	0.007	0.006	0.001	-0.001
% Not U.S. Born	0.004	-0.008	0.000	-0.002	-0.005	0.004
Faculty Unionized	0.377 **	0.467 ***	0.187 *	0.014	0.267 **	0.382 ***
Research I,II	0.227	0.141	-0.376 *	-0.229	-0.023	-0.214
Doctoral I,II	-0.017	-0.346	-0.328 *	-0.531 *	-0.069	-0.451 **
Comprehensive I,II	0.022	-0.153	-0.339 *	-0.191	-0.257 *	-0.220
Departmental Prestige	-0.072	-0.101 *	0.022	-0.018 *	0.049	-0.029
Doctoral Degree Prestige	0.093 *	0.035	0.015	0.011	0.014	0.029
Post Ph.D. Experience	-0.056 ***	-0.049 ***	-0.079 ***	-0.084 ***	-0.112 ***	-0.046 ***
Work Interruptions	-0.063	0.078	0.126	0.257 *	0.111	-0.049
Intercept	-2.246	-1.893	-1.846	-1.316	-1.124	-1.900
N	2392	2443	7241	3904	4503	4769
-2 Log Likelihood	2381.0	2295.9	4323.7	1725.8	3400.7	4757.8
d.f.	2362	2413	7211	3874	4473	4739
-2 Log Likelihood / d.f.	1.01	0.95	0.60	0.45	0.76	1.00
Pseudo R^2	.192	.174	.109	.065	.125	.165
Percent Correctly Predicted	67.3%	66.0%	68.8%	71.4%	67.6%	64.5%
P^2,	510.6 ***	466.7 ***	838.9 ***	260.7 ***	599.8 ***	860.7 ***
(d.f.)	(29)	(29)	(29)	(29)	(29)	(29)

The model fit statistics indicate that although all six models provide good fit to the data, substantial improvements in fit were obtained only by adding as predictors the female doctoral labor supply (Eq. 2), Carnegie classification, and individual workforce experiences (Eq. 6). The variables representing other aspects of labor supply, demand and opportunity which were hypothesized to vary across fields contributed little or not at all to explaining women's presence on science faculties.

To further explore how labor supply variables may have influenced women's faculty representation at different career stages, and for different cohorts, logistic regressions were performed separately on subgroups of faculty in Table 3. The first three equations separate faculty according to their tenure status: those in nontenure-track, tenure-track, and tenured positions. Patterns among fields in women's faculty representation found in the previous table are again suggested here, but most clearly for nontenure-track and for tenured faculty, the most numerous of the three groups. For faculty in both groups, women were relatively poorly represented in engineering, agriculture, physics/astronomy, earth/environmental sciences, and applied social sciences. Women were also relatively under-represented in sociology, but only among the tenured faculty, while among nontenure-track faculty women were underrepresented in computer science. Differences among the fields in women's faculty representation were much less distinct for those with tenure-track jobs. After controlling for the female doctoral supply, all but one of the fields were statistically indistinguishable from biology. But the health sciences stand out sharply for those on the tenure track, with women about 12% more likely to hold these positions than in biology and most other fields; this is even after adjusting for the situation of near parity which women experience in earning doctorates in health sciences.

There are also interesting similarities and differences by tenure status in the way that two measures of academic labor supply and demand affect women's faculty presence. The overall female doctoral supply and unionization of the faculty both had positive impacts on women's chances of occupying faculty positions regardless of their tenure status. There are some differences by tenure status in the impact of institution type, departmental prestige, and the prestige of doctoral credentials, but they neither alter nor account for the distinctive patterns among fields in women's chances of being science faculty members.

The last three equations in Table 3 separate faculty respondents by the year in which they earned the doctorate. Differences among these cohorts may signal important changes over time in the academic labor market for women scientists. Patterns in women's faculty representation across fields appear similar in many respects, but there are important shifts across cohorts. First, although it appears that, adjusting for doctoral labor supply, women's relatively poor representation in some fields compared to biology was most pronounced for the oldest cohort, in fact the relative differences in probabilities were larger among younger cohorts. For example, using delta-p transformations, the predicted odds that women held positions in engineering were 6% lower than in biology among the oldest cohort, but 12% lower for the 1970s cohort and 14% lower among the youngest cohort. The largest change in predicted probabilities applies to the youngest cohort, where those in the health sciences were 17% more likely to be female than those in biology. Another pattern in the findings worthy of note is the small effects of certain labor supply and demand variables that are confined to the 1970s cohort. It is only among this cohort that the odds that women would occupy faculty positions were depressed by sharp increases in women's representation in doctoral pools, by more rapid growth in the number of new doctorates, and by slower or negative growth in the size of the department's faculty. Finally, the impact of unionization in enhancing women's chances of securing faculty jobs seems limited to younger cohorts from the 1970s and 1980s.

In Table 4, we regroup the science fields into three cross-cutting groups according to Biglan's (1973) breakdown into hard versus soft sciences, pure versus applied sciences, and life versus nonlife sciences. As expected, net of other labor supply factors, women faculty were substantially better represented in the hard versus soft sciences, in pure rather than applied fields, and in life sciences rather than nonlife sciences.

DISCUSSION

Interpretations of our findings have to be placed within the confines of the methodological and conceptual limitations of the study: the exclusive focus on science fields; the historical period from which the data were derived; the use of cross-sectional data matched with aggregate field level and institutional data to discern dynamic trends; and the inability to model all the leading conceptual approaches to explaining gender gaps in academia. Further research will be necessary to determine whether our findings apply exclusively to science faculty. We may be overlooking some institutional and disciplinary factors that are responsible for women's better overall representation in some non-science fields (e.g., education, social work). Still, the findings document appreciable variation in women's representation across science fields. Moreover, it can be argued that science constitutes a critical and strategic test of gender equity issues in academia because debates about whether gender differences in academic careers are due principally to labor supply, institutional forces, or individual differences in scholarly merit are no more sharply drawn than in science. At issue is the extent to which scientific evaluation is shaped by a culture where prevailing "gender assumptions" distorts norms of universality and merit (Keller, 1985; Knorr-Centina, 1981; Reskin, 1980). Systematic efforts in future research to capture

TABLE 4. Logistic Regression Using Biglan Disciplinary Breakdown to Predict Whether Faculty Position Is Held by a Woman[a]

	B	B
“Hard” versus “Soft”	0.259 ***	0.311 ***
“Pure” versus “Applied”	0.276 ***	0.375 ***
“Life” versus “Non-Life”	0.327 ***	0.321 ***
% Female: 1976-1988 Ph.Ds.	0.051 ***	0.047 ***
Female Ph.Ds. 1976-1988 > 15%	0.335 **	0.356 ***
Change in % Female Ph.Ds.	-0.005	-0.003
% Change in # of Ph.Ds.	0.001	-0.002
% Departmental Growth	0.001	0.000
% Outside Academe	-0.000	0.002
% Not U.S. Born	0.003	-0.003
Faculty Unionized	0.178 ***	0.292 ***
Research I, II		-0.070
Doctoral I, II		-0.287 **
Comprehensive I, II		-0.211 *
Departmental Prestige		-0.056 *
Doctoral Degree Prestige		0.024
Post Ph.D. Experience		-0.081 ***
Work Interruptions		0.089 *
Intercept	-3.595	-2.540
N	13177	13177
-2 Log Likelihood	10403.9	9689.7
d.f.	13165	13158
-2 Log Likelihood / d.f.	0.79	0.74
Pseudo R^2	.105	.152
Percent Correctly Predicted	62.1%	68.7%
P^2, (d.f.)	1460.6 *** (11)	2174.9 *** (18)

[a]Hard sciences: Physics/Astronomy, Chemistry, Earth/Environmental Sciences, Biology, Math, Computer Science, Engineering, Agriculture, Health. Pure sciences: Physics/Astronomy, Chemistry, Earth/Environmental Sciences, Biology, Math, Economics, Political Science, Psychology, Sociology, Anthropology/Archeology. Nonlife sciences: Physics/Astronomy, Chemistry, Earth/Environmental Sciences, Math, Computer Science, Engineering.
*$p < .05$; **$p < .01$; ***$p < .001$.

these cultural differences may help explain the persisting differences among fields in women’s faculty presence.

The relevance of the trends from pre-1990 data to the current state of academia is also open to question. Some of our findings by doctoral cohort suggest that the dynamics underlying changes in the gender composition of academia were themselves shifting even during the period examined. For example, the unusually high rate at which women doctorates in the health sciences were incorporated into faculty jobs commenced only in the 1980s, and the relative underrepresentation of pre-1970 cohort women on psychology faculties disappeared when examining younger cohorts. Moreover, only the 1970s cohort of women doctoral recipients was subject, albeit to a very modest degree, to lower chances of securing faculty jobs due to relative over supplies of doctoral labor and stalled growth in faculty job openings.

Still, there are strong indications that broader patterns in our results have not changed markedly in the last decade. According to a National Science Foundation (1998) study, the proportion of women hired as science and engineering faculty still lagged behind their proportion of new doctoral recipients, and the segregation of female scientists into a few fields has persisted, along with their acutely severe underrepresentation in physics and engineering. The more recent NSF data are consistent with our results that indicate that the gender composition of the science faculty at the end of the 1980s was clearly not simply a function of gender gaps in doctoral production. Women's constricted progress through the educational pipeline accounted for much, but not all, of the variability in their presence across scientific and engineering disciplines. Even after controlling for differences among fields in the female doctoral labor supply, women enjoyed enhanced odds of holding faculty positions in the biological and health sciences compared to most other science fields, and relatively poor odds in engineering, physics/astronomy, earth/environmental sciences, and agriculture. The persisting differences among fields cannot be explained by sharp bursts of growth in women's share of doctorates; by different rates of growth in overall supply of doctoral labor or departmental demands for it; by varying employment opportunities outside academia; by competition from foreign-born scholars; by differences in faculty unionization or employment in research oriented institutions; nor by gender differences in individual training and work history characteristics.

Nor did the differences among fields align solely along hard versus soft, pure versus applied, or life versus nonlife science dimensions. After dichotomizing fields along these axes and adjusting for women's availability in the doctoral labor pool, women's faculty representation was generally higher in hard, pure, and life sciences, as previous scholarship might lead us to expect. However, a more detailed breakdown of fields shows that women's representation varied more within applied fields (e.g., health sciences versus engineering) than between applied versus pure fields considered collectively. Similarly, the life sciences include fields at the extremes of faculty gender composition, from the highest relative level of representation of women faculty (health sciences) through moderate (biology and many social sciences) to extremely sparse representation (agriculture). Further, after controlling for doctoral labor supplies, women faculty appeared about equally well represented in some hard sciences with central paradigms, such as biology, as in most of the soft sciences lacking theoretical and methodological consensus.

Is there something distinctive about the academic fields that stand at the extremes of our findings? Here we may only speculate. The health sciences, where the youngest cohort of women enjoyed the highest odds of securing tenure-track faculty positions, are centered in medical schools that have been at the vortex of legal and social controversies over affirmative action. The intense scrutiny surrounding medical school admissions over the last 25 years has perhaps generated a higher level of awareness of the presence of discrimination and more determined support for its elimination. At the same time, vigorous affirmative action policy has dramatically transformed the composition of medical students and brought the sex ratio close to balance. Has this transformed medical school culture in ways that have affected faculty as well? Unlike most other sectors of academia, medical school faculty expanded sharply after 1980, and women joined in great numbers, especially at the assistant professor rank (Association of American Medical Colleges, 1992). Medical school faculties also expanded in specialty areas where women physicians are especially prominent—internal and family medicine and pediatrics. Women faculty in medical schools, however, still lag behind their male counterparts in advancement in rank. Women's better representation among faculty in the health sciences might also be attributed to their male peers' search for more lucrative employment outside academia. However, our results control for the extent to which doctoral recipients in the field opt for non-academic employment. There is evidence that gender gaps in faculty salaries are unusually high in the health sciences (Bellas, 1993), perhaps because of gender differences in medical specialties. Our findings, then, may reflect differences in the medical specialties pursued by women and men, and the unique structure of medical education. We can rule out one explanation along the same lines: that the findings reflect unique patterns of sex segregation in nursing. Although nursing accounted for a third "health sciences" respondents, results showing women to be particularly better represented on health science faculties remained essentially unchanged when we excluded the nursing field (results not presented).

At the other extreme, what explains the relatively poor rate at which doctoral level women in agriculture, engineering, and the physical sciences secured academic jobs? One possibility is that unlike health and biological sciences, women in these particular hard science fields have not developed the critical mass that is necessary to overcome tokenism and isolation and to gather sufficient power to compel institutional changes (Etzkowitz et al., 1994; Kanter, 1977; Tolbert, 1986). Although our results showed that a critical mass of women in the doctoral labor supply enhanced their chances of being employed in faculty jobs when institutional and individual factors were controlled, controlling for critical mass did not account for the distinctive pattern in women's faculty representation by field of science. Perhaps the lack of critical mass is more or less problematic depending on whether the negative effects of tokenism are compounded by other factors we did not examine, such as in academic cultures where women are perceived as working in low status jobs. Yentsch and Sindermann (1992) suggested that women doctorates in the physical sciences and engineering often are not viewed as full-fledged academics because they are commonly trapped in academic ghettos—employed as research associates in labs and institutes, on "soft-money" lines, or as part-time instructors. The marginalized position of women in the physical sciences and engineering may be exacerbated by their greater tendency to be part of an academic couple, compared to their male counterparts or women in other fields (Stephan and Kassis, 1997). Facing the dual academic career dilemma, they are more likely to accept research or "courtesy" appointments without faculty status, and experience attendant problems of a "trailing" spouse label. In fields where these roles are common for women, it is not surprising that the culture would fail to support recruitment of women for tenure-track faculty jobs and their subsequent career progress. In contrast, in most of the biological and social sciences, a critical mass of women may serve as a magnet for female scientists at the pre-doctoral level (increasing perceptions among college students that these fields are "women-friendly"), and the postdoctoral level (as women faculty promote gender parity in their departments and colleges).

The marginalization of women in lower status academic jobs is also a concern in fields that have been much more extensively "feminized" than the physical sciences. In our findings women sociologists were better represented in nontenure-track positions than in the doctoral pool, but remained substantially underrepresented in tenured positions even after other labor supply and demand factors were controlled. Women may be welcomed to academic positions in fields like this, but directed to different types of positions than their male counterparts. Women, it's been suggested, handle academia's "housework," the unglamorous tasks of undergraduate teaching and advising. Patterns in other results, however, offer cautions about generalizing across fields. There are numerous similarities across the social sciences, including those like sociology and psychology, which have rapidly incorporated women in graduate programs, and those where men still predominate numerically, like economics and political science.

The nature of the data we examined leave us unable to address empirically another way of explaining the pattern of unexplained differences in women's faculty representation—that they are a reflection of cultural differences among fields. There are numerous ways that the culture of academic disciplines have been described as more or less inhospitable toward women. For example, Gornick (1990) noted that natural scientists tend to believe that their actions are guided only by intellectual objectivity, which inhibits recognition of their own

discriminatory or irrational actions. Fields differ in the extent to which they tolerate or promote bad mentor-protegee relationships in graduate school (Swazey, Anderson, and Louis, 1993), and bar women from full access to informal nomination and insider information networks (Cole, 1979). Some academic environments provide strong sociocultural support for discriminatory behavior, creating norms that diffuse throughout the discipline (Warner and DeFleur, 1969). Some fields more than others may be characterized by male-centered career models demanding hyperachievement and total work commitment, to the exclusion of other life realms, with a spouse at home to lend support (Etzkowitz et al., 1992). These expectations have been found to pervade the cultures of engineering and computer science (McIlwee and Robinson, 1992; Wright, 1996), fields where we find women were particularly poorly represented. In fields whose cultures promote such ideas, women may face intense statistical discrimination at the hiring stage, as search committee members and hiring authorities make assessments of individual women on the basis of their beliefs that women in general are less likely to adopt or succeed within the "male" model of career success. Women employed in these settings may find that balancing a scientific career and a satisfying personal life is virtually impossible.
A major task for future research in this area is to develop comprehensive ways of measuring the severity of these cultural obstacles to women's participation in ways that allow for comparisons across fields.

Our findings may also be considered from the viewpoint of arguments that there are sex composition effects *per se* as women's increasing participation in a field changes perceptions of its comparable worth, typically by devaluing work done by women (Reskin, 1988). As women become concentrated in particular occupations or academic fields, the work or the field may become associated with their lower status. There is a strong inverse relationship between women's representation in an academic field and the average salaries of both women and men in the field (Bellas, 1994). It is less clear whether the penalty for doing "women's work" in academia is more costly to the women in these fields than to their male colleagues.[3] Although our study is unable to independently assess the role of sex composition effects on individual faculty outcomes, some of our findings are consistent with the view that women's career advancement is compromised in heavily feminized fields. Compared to biology, women were less well represented among the tenured faculty in some of the social sciences, where women come closest to numerical parity with men (sociology). However, we found that fields and subfields with a critical mass of women—more than 15%—had higher representation of women faculty. If women in relatively feminized fields pay a price through diminished promotion chances and stagnant salaries, it appears that token levels of female representation are even more perilous roadblocks to entering the professoriate.

Another limitation of the study—the use of cross sectional data—makes strong causal interpretations unwise. In combination with their possible historical specificity, the findings support only quite general implications for higher education policy and practice. One lesson is clear. The size of the doctoral labor supply of women in each field and subfield is a sizable but not uniformly consistent predictor of their level of faculty representation. Efforts to maintain and increase the entrance and persistence of women in doctoral training are critical, yet insufficient means of redressing gender gaps in faculty representation. Another lesson is the need to remain attentive to patterns of sex segregation among sub-fields within disciplines, including at the doctoral training level. The study's failure to find that the gender composition of the faculty is strongly influenced by over supplies of doctoral recipients, by low demand for faculty, by nonacademic job opportunities or by competition by foreign-born scholars suggests that these are unconvincing excuses for women's continuing underrepresentation among the science faculty in U.S. colleges and universities.

The consistent findings showing that unionized settings increased the odds that women held science faculty positions suggest that a more constructive way to address the gender gap is to emulate the formalized personnel practices and appeal structures—and perhaps the family-friendly employment policies—that unionized settings help to establish. These formalized practices may lend a counterweight to disciplinary cultures that erect barriers to women's employment on science faculties. Transforming disciplinary cultures that reward a highly competitive work style and the merging of personal life with scientific work to a more family-friendly or "female" model of doing science may be the most effective way to redress the gender imbalance in fields like engineering (Etzkowitz et al., 1992). However, changes in institutional policies could also do much to improve the situation, such as abandoning prohibitions against hiring academic couples and lengthening probationary periods before tenure review. These changes would undoubtedly be challenging to implement, requiring careful planning and much persuasion of those who remain unconvinced of the need for gender parity in academic science. Without action to repair the ongoing leaks at the end of the pipeline, however, this study suggests that the science faculty will continue to be gender-segregated and gender-imbalanced.

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ENDNOTES

1. Apart from the difficulty of adequately exploring all these issues in one paper, we are unable to fully address the "devaluation" argument with cross-sectional outcome data. The beneficial impact on women's faculty recruitment of women's increasing representation among administrators and students is documented elsewhere (Kulis, 1998).
2. In our 1989 SDR faculty sample, the average man with tenure passed that landmark in 1975, while the average woman with tenure received it five years later. More than 20% of the men with tenure received it before 1970, but only 8% of the tenured women.
3. There is tangential evidence that salaries for university administrators decline even more steeply for women than for men as women's representation within particular administrative jobs begins to exceed 30% (Pfeffer and Davis-Blake, 1987). A study of Israeli universities suggests that gender inequities in academic rank are more pronounced in fields where women are better represented and narrower where their representation is sparse (Toren and Kraus, 1987).

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