Why Are Some Academic Fields Tipping Toward Female? The Sex Composition of U.S. Fields of Doctoral Degree Receipt, 1971–2002

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Using data on the number of men and women who received doctorates in all academic fields from 1971 to 2002, the authors examine changes in the sex composition of fields. During this period, the proportion of women who received doctorates increased dramatically from 14 percent to 46 percent. Regression models with fixed effects indicate no evidence that fields with declining relative salaries deter the entry of men, as would be predicted by the queuing theory of Reskin and Roos. Consistent with the devaluation perspective and Schelling's tipping model, above a certain percentage of women, men are deterred from entering fields by the fields' further feminization. However, the rank order of fields in the percentage of women changed only slightly over time, implying that, to a large extent, men and women continued to choose fields as before, even when many more women received doctorates. The findings on the effects of feminization on salaries are mixed.

Between 1971 and 2002, women moved from being 14 percent to 46 percent of those who received doctorates (National Center for Education Statistics, NCES, 1973–2003). As Figure 1 shows, women accounted for all the net growth in the number of doctoral degrees received in that period. This was part of a larger change in the gender system involving women's increased continuity of employment, the organized women's movement, and the federal government's commitment to equal opportunity. As more college women contemplated careers, more decided to get doctorates. With this massive feminization of the entire doctoral system, the percentage of women increased in almost all fields. Although the math-intensive fields that started the period with the least women still had fewer women than other fields in 2002, even their percentages of women increased dramatically. For example, electrical and electronic engineering went from 0.3 percent to 12 percent female, math from 8 percent to 26 percent female, chemistry from 8 percent to 33 percent female, physics from 3 percent to 16 percent female, and economics from 7 percent to 28 percent female.

The fields with the highest percentage of women today are those that already had a high percentage of women in 1971 relative to other fields. But because so few women obtained Ph.D.s in 1971, the vast majority of those who got doctorates then were men even in fields with the highest percentage of women. In some of these fields, well over half the degrees go to women now. For example, doctorates awarded in communications rose from 16 percent to 57 percent female between 1971 and 2002. In the same period, educational administration went from 13 percent to 62 percent female, industrial and organizational psychology went from 20 percent to 54 percent female, microbiology went from 18 percent to 47 percent female, psychology went from 24 percent to 64 percent female, anthropology went from 26 percent to 55 percent female, sociology went from 21 percent to 61 percent female, and English went from 30 percent to 58 percent female. Some fields are tipping toward becoming all female.[1]

In this article, we explore changes in the sex composition of fields, testing some hypotheses about causes and consequences. We do not attempt to explain why some fields have consistently attracted or admitted more women than men—for example, why more math-intensive fields are more "male" while fields involving the greater use of language and study of humans are more "female." (On these important questions, see Eccles 1984; Fiorentine 1988a, 1988b; L. Friedman 1989; Hyde 1981; Jacobs 1985, 1989, 2000; Kavrell and Petersen 1984; Linn and Hyde 1989; Lueptow, Garovich-Szabo, and Lueptow 2001; Marini and Brinton 1984; Marini and Greenberger 1978; Tartre 1990;

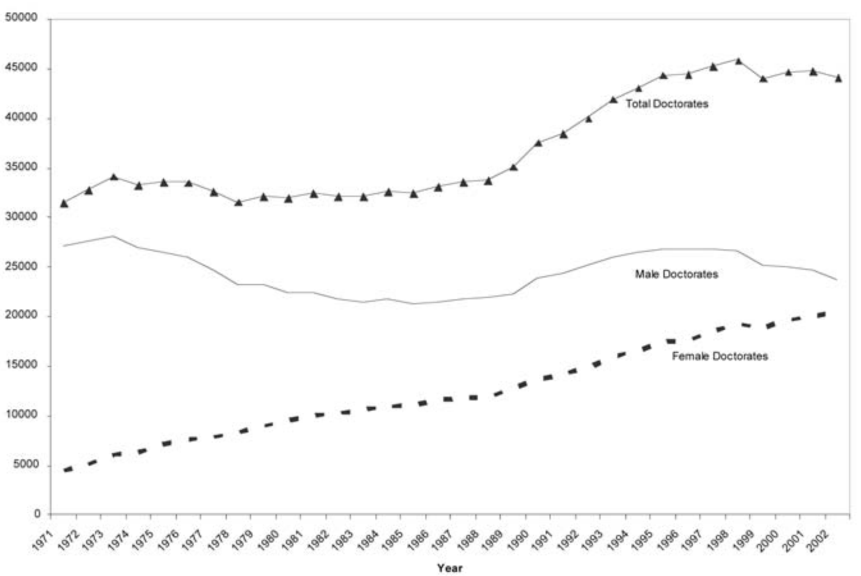

Figure 1. Number of Doctorates Granted in the United States, 1971–2002

Wilson and Boldizar 1990; Xie and Shauman 2003.) Rather, we test hypotheses about the determinants of changes in the sex composition of fields of doctoral study.[2] We also test hypotheses about the determinants of changes in fields' starting academic salaries.

One hypothesis can be thought of as a demographic baseline model; it considers how much of the change in the sex composition of fields is dictated simply by the increased number of women who get doctorates, assuming no change in men's or women's selection of fields. Another view is that the presence of too many women deters men from selecting a field either because of stigma or because men fear that feminization will lead to lower rewards. This hypothesis is predicted by the devaluation perspective of gender studies and by an analogy to Schelling's (1971, 1978) tipping model, which was introduced to understand residential racial segregation. The devaluation view also predicts that as fields feminize, their relative salaries decline. The queuing thesis of Reskin and Roos (1990) predicts that as the relative salaries of fields decline, men decreasingly choose to enter them, leading to feminization. We test these ideas with data on the number of women and men who received doctorates in detailed fields in each year from 1971 to 2002 and data on the average starting salaries for assistant professors in detailed fields by year.

THEORETICAL PREDICTIONS

Demographic Baseline Model

A baseline model says that there will be little change in segregation as more women obtain doctorates; the sex composition of those who receive doctorates in each field will change only as dictated by increases in the proportion of all doctorates that go to women, with no change in the propensity of either sex to choose particular fields of doctoral study. This is a useful hypothetical demographic baseline model and underlies many segregation indices (that try to adjust for changes in the relative sizes of the fields and representation of the two sexes overall). Against this view is the supposition that the same modern ideal of universalism would yield both the integration of women into higher levels of academic study *and* the desegregation of fields of study. However, on the basis of their cross-national study of gender segregation in higher education, Charles and Bradley (2002) concluded that "ideals of universalism do more to undermine vertical than horizontal segregation." By vertical segregation, they meant each higher level of degree (two year, four year, and postgraduate) having fewer women. By horizontal segregation, they meant the segregation of fields of study at one level of degree, such as the doctorate. Charles and Bradley showed that the extent to which women in modern nations have integrated higher levels of the educational system has little correlation with the degree of segregation of fields. Thus, if the United States fits their cross-national generalization, we would not necessarily expect fields to be integrated as more women get doctorates.

Devaluation and Tipping Theory

Two related perspectives predict that as women become more numerous in a field, men are less desirous of entering it. According to these views, men avoid fields as the fields feminize because they want to avoid the stigma of being in a field with too many women or because they are afraid that the feminization will lead to lower pay, which they want to avoid. Thus, initial feminization caused by a greater entry of women will lead to further feminization caused by the decreased entry of men, leading in some cases to tipping. This idea is consistent with the devaluation perspective in gender studies, which views the cultural devaluation of women as leading to a devaluation or stigmatization of all things associated with women, including styles of clothing, names, leisure activities, fields of study, and jobs (England 2001; Williams 1993).

We expect feminization to affect men's choices more than women's because although both sexes have some motivation to avoid the devalued female fields, gendered socialization (by peers, parents, female role models, or the media) encourages women to choose heavily female fields. Thus men, more than women, will avoid fields as they feminize, although women may be somewhat motivated to avoid them as well.

The hypothesis that men's responses to increased feminization may exacerbate tipping is also inspired by Schelling's (1971, 1978) argument that whites' unwillingness to live in neighborhoods with "too many" African Americans can lead neighborhoods to tip toward all African American once the percentage of African Americans rises above some threshold. Schelling contended that initial increases in the percentage of African Americans in a neighborhood put the neighborhood over the comfort level for some whites, leading whites to move out or not to move in. This situation creates a further increase in the percentage of African Americans, putting it above the comfort level of an even larger proportion of whites. Eventually, neighborhoods tip from largely white to largely black. Underlying the process is an asymmetry: Whites' bias against living with blacks is greater than blacks' bias against living with whites. This idea is parallel to the idea that while each sex is encouraged to choose roles with a higher proportion of its own sex, men's resistance to taking on a role that associates them with women is greater than women's resistance to a male-associated role. It is this asymmetry that, in Schelling's model, makes an integrated equilibrium impossible. D. Friedman and Diem (1993) suggested that this model could be applied to occupational sex segregation; here, we apply it to fields of doctoral receipt.

How would this process work when applied to fields of doctoral study? Male college students who are choosing majors and considering fields of doctoral study may reject certain fields because they observe a high percentage of women among the undergraduate majors, graduate-student teaching assistants, or young assistant professors in the field. What counts as "too female" will be lower for men than for women. If this hypothesis is true, then any initial feminization in fields that comes from the increase of women in the doctoral system will lead men increasingly to avoid majoring in or applying for doctoral study in the most female fields, which, in turn, will lead to further feminization of these fields and lower pay.

The devaluation perspective was developed to explain the relatively low pay of predominantly female occupations. In cross-sectional analyses, there is substantial support for the claim that salaries of predominantly female jobs are lower than those of predominantly male jobs that require comparable amounts of education and skills (England 1992; Sorensen 1994; Steinberg 2001) and some support for the claim that increases in the percentage of women in fields lead to decreases in the salaries in these fields (Baron and Newman 1989; Catanzarite 2003; Karlin, England, and Richardson 2002; Pfeffer and Davis-Blake 1987; Snyder and Hudis 1976; but see England, Allison, and Wu forthcoming). Research by Bellas (1994) showed that academic salaries are lower in fields that are more heavily female, controlling for academic rank and the average salaries in nonacademic jobs that are available to those with doctorates in the field. Moreover, Bellas (1997) found that the percentage of women in academic fields in 1978 had a negative effect on women's average entry-level salary in 1988 net of the average entry-level salary in 1978. Thus, the devaluation perspective and some past evidence predicts that as the professorate in a field feminizes, its relative pay will go down.

Queuing

Queuing theory reverses the causal order between the sex composition of those in a job and rewards, such as pay. While devaluation theory states that feminization lowers pay, the queuing perspective states that reductions in pay (or in other rewards) lead to the feminization of an occupation (see Reskin and Roos 1990; Strober 1984; Strober and Catanzarite 1994). In this view, employers' preferences for men cause better jobs to become disproportionately male. Given these preferences, when hiring for high-paying (or otherwise desirable) jobs, employers are typically able to get men, but when hiring for low-paying jobs, they often have to settle for women even if they prefer men, since men gravitate first to the high-paying jobs. In such a process, even though women also prefer high-paying jobs, they typically are able to get only the jobs that men do not want. It is when jobs pay badly *relative to* their educational requirements that employers are less likely to be able to hire men, and the jobs are likely to end up disproportionately female. Reskin and Roos (1990) referred to this view as "queuing"; we use their term here. Strober and Catanzarite (1994) referred to it as the "relative attractiveness" theory of segregation; the more attractive a job is, the more likely it is to come to be filled by men. If this is roughly what is happening, then longitudinal data should reveal that the salaries in fields at one time affect the sex composition of these fields at a later time.

Using national occupational data, Karlin et al. (2002) and Catanzarite (2003) failed to find a positive effect of early pay on the later number or percentage of men in a field. Pfeffer and Davis-Blake (1987) did find support for the queuing hypothesis; they found that universities whose administrative jobs paid less had more feminized administrations in a later period. (They also found support for the opposite causal arrow, that early percentage female reduced later pay.) The only longitudinal study involving faculty salaries found that 1978 salaries had the predicted significant negative effect on the percentage of women in fields in 1988 (Bellas 1997).

How can the queuing perspective be tested with regard to fields of doctoral study? If relative pay affects men's choices of the fields to which they apply for graduate study, it would be consistent with queuing theory. This perspective would make sense only if men somehow obtain (at least rough) information on relative salaries by the time they decide on a field of graduate study. For example, if the relative salaries in computer science increased because of a greater demand, more men would choose this field of doctoral study. In this view, women are just as interested in money as are men, but are often unable to gain access to lucrative jobs because employers discriminate against them in hiring if they can (e.g., if the supply of men is adequate for the number of jobs). Given the costs of attaining a doctorate, women may be expected to avoid fields in which they fear they will not be hired after many years of study. Such fears and the discrimination underlying them could make women's choices of fields less positively responsive to pay levels than men's.

Hypotheses

Drawing on the theoretical perspectives just discussed, we tested Hypotheses 1 and 2, which are based on the demographic baseline model; Hypotheses 3 and 4, which are based on the devaluation and tipping perspectives; and Hypothesis 5, which is based on the queuing perspective.

> *Hypothesis 1:* The degree of sex segregation of doctoral fields does not decline.

> *Hypothesis 2:* Fields do not change their relative sex composition of doctoral recipients over time.

> *Hypothesis 3:* The earlier percentage of women who obtained doctorates in a field has a negative effect on the later number of men who get doctorates in the field.

> *Hypothesis 4:* The earlier percentage of women who obtained doctorates in the field has a negative effect on the later average starting salary in the field.

> *Hypothesis 5:* The earlier average starting salary of assistant professors in a field has a positive effect on the later number of men who obtain doctorates in the field.

DATA AND MEASURES

Our main source of data was NCES (1973–2003), which publishes the number of women and men in the nation who received bachelor's and doctoral degrees in all fields of study each year. We used its series for academic years 1970–71 to 2001–02. The system used by NCES to classify degrees into fields of study changed several times during the period. The most significant changes in classification occurred in 1983, when the number of categories greatly increased. Some changes over time were simply minor changes in the names of fields (e.g., from agricultural business to agricultural business and agribusiness operations). In these cases, we simply adopted the later name. When more detailed categories appeared, the new fields were often collapsed into the appropriate broader category that was previously used (e.g., the new detailed categories of animal breeding and genetics, animal health, and animal nutrition were put into the previous broader category of animal science). In other cases, the new fields were put into the "other" category for the relevant broader field. The "other" category, which appears for all the broadly defined fields, is what changed most over time as more fields that could not be classified elsewhere were added to that category. (However, such fields constituted a tiny portion of the degrees that were awarded.) Finally, a few fields disappeared altogether over time (remedial education, African languages, Indic languages, and two interdisciplinary fields), and Women's Studies did not appear in earlier years; since these were tiny fields, we eliminated them. From these classifications, we constructed a categorization system of 263 fields for the 32-year period.[3]

After we removed tiny fields that had fewer than 150 doctorates over the entire period, we had 202 fields. We then created a data set with field-year as the unit of analysis for all academic years from 1970–71 to 2001–02. (We refer to academic years in terms of the later year, since degrees are generally granted in the spring.) The data set contained the number of men and women who received degrees in each field in each year; it had 6,464 observations (202 fields times 32 years). Since all our regression models include lagged independent variables that averaged scores from 4 to 7 years earlier, the first year that is represented in the data was actually 1978. Thus, the maximum *N* for our regressions was 5,050 (202 fields times 25 years). Some of these observations were lost when a field had no one in it for a given year, and thus the proportion female was undefined (because of the 0 denominator), creating an *N* of 4,411 in our basic model.

We also used data on the salaries of academic faculty by field and year, obtained from the College and University Personnel Association (CUPA). CUPA reports the average annual salaries of new assistant professors (those in their first year) by academic fields in public and private institutions, respectively, and the number of new assistant professors in the year for the public and the private institutions in its report. We took a weighted average of the public- and private-sector salaries. For each field, we created a weight on the basis of how many new assistant professors were in the institutions that reported from each sector. We used this salary measure, computed separately for each year and field, as a measure of the relative attractiveness of fields according to the salaries they offered after the receipt of the doctorate. Of course, a limitation of the measure is that, in some fields, many doctorates are going into nonacademic jobs, but to the extent that fields with lucrative nonacademic salaries thereby have their academic salaries driven up relative to other fields, this is still a useful indicator of the earnings potential of the field of doctorate study.

These salary data were merged onto the data set described earlier, constructed from the NCES data, with years by detailed fields as the units of analysis. However, CUPA used less detailed fields of study (*N* = 53). We merged the CUPA salary figure for a broader field with all the records of the detailed NCES fields. For instance, the field "mathematics" in CUPA matches four fields in the NCES data: general mathematics, applied mathematics, statistics, and other mathematics. Therefore, these four NCES fields have the same value on the new assistant professor salary variable. The CUPA salary data were available only from 1978 to 1998. Moreover, 13 fields had so many missing values in the CUPA data (in more than 10 of the years) that we had to drop them. However, the total number of doctorates in the dropped fields was less than 2 percent of all doctorates, since they were small fields. For the fields with missing values in less than 10 years in the 20-year period, we imputed the previous year's salary for the missing values. When the missing value was in the first year of data, we substituted the salary from the next year. We made 31 imputations, consisting of 8 percent of the total number of observations. Given the loss of fields to missing data and the fewer years available for analyses, including salary, models that included salaries had 2,378 observations.

CUPA salary data are in current, rather than constant, dollars. Of course, the same nominal salary in 1978 and 1998 implies different purchasing power because of inflation. Rather than convert to constant 1998 dollars, we left the measure in current dollars, but used a fixed-effects modeling strategy (discussed later) that included dummy variables that controlled for each individual year. In this way, period trends in both inflation and changes in real salaries that affected all fields were netted out of the models, so effects involving salaries can be interpreted as pertaining to the relative salary of the field in the given year—whether salary is a dependent or an independent variable.

The descriptive statistics that we present include trends in the sex composition of doctoral degree recipients as a whole and in the 18 largest fields. These 18 largest fields were responsible for 48 percent of all doctoral degrees across all the years combined. We also computed the most common measure of segregation, the index of dissimilarity (D) (Duncan and Duncan 1955) to measure the extent of sex segregation by field for each year, using all 202 fields.[4] The interpretation of D is often explained in a "shorthand" way as the percentage of women (or men) who would have to "trade" fields with men (or women) for both sexes to be represented in all fields in proportion to their representation in the overall system. If women received 14 percent of all doctorates, as they did in 1971, then they would have to constitute 14 percent of those in a field to be proportionately represented; if women received 46 percent of all doctoral degrees, as they did in 2002, they would have to constitute 46 percent in each field. This shorthand interpretation is somewhat misleading, however, because it describes only the numerator of D. More precisely, the numerator is the number of "trades" of women and men required for evenness, as was just described, and the denominator is the maximum number of such possible integrative "trades" starting with complete segregation. The denominator is maximized when each group is 50 percent of the population. D is implicitly weighted; big fields contribute more. This implicit weighting is appropriate if our interest is in the segregation experienced by the average person in the system. For this reason, we prefer D to other measures of segregation.

REGRESSION MODELS

To test the hypothesis that men increasingly avoid fields of doctoral study as the salaries in those field decline or as the proportion of women in them rises, we used a negative binomial, fixed-effects regression model (Allison 2005; Allison and Waterman 2002; Cameron and Trivedi 1998). We chose the negative binomial model because when we attempted to fit models based on the Poisson distribution, there was excessive overdispersion, as measured by the deviance divided by the degrees of freedom. This excessive overdispersion commonly occurs when the variance of the counts is much larger than what would be expected on the basis of the Poisson model (Cameron and Trivedi 1998:11). The variance is large; the number of doctorates in a field varies from a few to thousands per year.

Although our main interest was in predicting the number of male doctorates, we also present parallel models predicting female doctorates. The main independent variables were the lagged proportion female of those who obtained doctorates in the field and (in some models) the lagged average salary for new assistant professors in the field; the dependent variable was the (natural log of the) number of men (or women) who got doctorates in the field about five years later. We included squared terms for proportion female because we found them significant. Although devaluation theory does not specify whether the shape should be linear or nonlinear, just that the effect would be negative, it is not inconsistent with the theory to imagine that the stigma of being in a field that is "too" female is nonexistent or trivial until women reach a certain critical proportion and then that each successive increment of percentage female has a larger effect in stigmatizing the field for men. A cubic term may be significant as well if, after a certain point, the field is already seen as "female" and further increments do nothing. However, our tests never found cubic terms significant, so we do not show models that include them.

Let y_{it} be the number of male doctorates in year t for field i. We assume that y_{it} has a negative binomial distribution with an expected value μ_{it} and a variance given by $\mu_{it}(1+\theta_{it})$, where θ is an overdispersion parameter. (When $\theta = 0$, the distribution is Poisson with a variance equal to the mean.) The negative binomial is an attractive choice because it directly models the discrete and highly skewed distribution of doctorate counts. Some fields give less than 100 doctorates a year, while others give thousands. The negative binomial model is much less restrictive than the Poisson distribution, which does not fit these data well owing to overdispersion.

In turn, the expected value μ_{it} is assumed to be a log-linear function of explanatory variables:

$$\ln\mu_{it} = \delta_i + \beta\mathbf{x}_{it},$$

where $\mathbf{x}_{it}$ is a vector of explanatory variables that vary with time and across fields and δ_i is an intercept specific to each field. The two time-varying explanatory variables are both lagged approximately five years behind the dependent variable. Ehrenberg (1992) showed that the median time from being enrolled to receiving a doctorate varied from 5 to 7 years in the 1970s and 1980s, so we wanted a lag of approximately this length. To avoid large year-to-year fluctuations in small fields, we averaged the percentage of women who obtained degrees in the field 4, 5, 6, and 7 years before the year in question and used this (unweighted) average as the independent variable of interest. The average year of the lag is 5.5 (for simplicity, we refer to it as 5 years). We also experimented with slightly longer lags, but the results did not change much. We used the same procedure for lagging the salaries of new assistant professors, averaging the score from 4 to 7 years earlier. Because fields up to 7 years earlier were averaged to get the lagged independent variable of interest, our regressions begin with 1978 (because the lagged variable for this year came from 1971–77 data). Since data on salaries were available only from 1978 to 1998, the regressions for models that include salary begin with 1985 and contain years through 1998.

In some models, we also controlled for the natural log of the number of men who got baccalaureate degrees in this field (exactly) five years earlier to control for the available "pipeline" of people with a major in the area. (In models predicting women's doctoral degrees, this pipeline control is for the log of the number of women who got baccalaureate degrees five years earlier.) We did not average several years to get the lagged value of the number of male baccalaureate degrees in the field, as we did for the lagged proportion female of the doctoral field, since in almost fields a large number of baccalaureate degrees are granted each year, and the number does not fluctuate drastically from year to year, so there is no need for a moving average. However, men's reluctance to choose feminizing fields as undergraduate majors may be part of the mechanism of how feminization deters men, in which case we did not want to adjust its effect out. Thus, we also estimated models without this control.

The δ_i term is what makes this a fixed-effects model, implicitly controlling for all stable (although unmeasured) characteristics of each field. For example, if some fields are always larger than others because they are attractive to students, these size differences are adjusted for. Similarly, if a field has an unmeasured characteristic, such as requiring high math scores that would eliminate more women than men, and this characteristic has a relatively constant effect on its sex composition, this characteristic is also implicitly controlled. If a field has an enduring social label as a "man's" or a "woman's" domain and this label affects which gender has more social support for choosing the field as a career, this is controlled. One can think of fixed-effects models as calculating, for each field, the extent to which changes over time in percentage female were followed by later changes in the number of men who received doctorates; then the magnitudes of these effects are averaged across fields. Although we can never be sure that we are picking up only causal effects outside true experiments, we believe that fixed-effects models remove more omitted-variable bias than do other available options precisely because they control for all unchanging characteristics of fields, even though they are unmeasured. Of course, one weakness of the method is that we are not able to control for changing characteristics of fields (relative to other fields).

We estimated the fixed-effects negative binomial models with conventional software for negative binomial regression, directly estimating the δ_i terms by including dummy variables for all but one of the fields. The use of dummy variables to estimate fixed effects is problematic for logistic regression and many other nonlinear models (Hsiao 1986), but Cameron and Trivedi (1998) proved that this method is valid for Poisson regression. Allison and Waterman (2002) demonstrated by simulation that this result also extends to negative binomial regression models. However, they also found that conventional estimates of standard errors are biased downward, a bias that is easily correctable by multiplying standard errors by the square root of the deviance divided by its degrees of freedom. We implemented that correction here.

The models we estimated predicting the number of men getting doctorates in a field also include an "offset" term to control for the total number of doctorates awarded to men in the given year in all fields combined (assigned to all field years for the given year). Analogously, the total number of women getting doctorates in all fields is controlled in models predicting the number of women in a field. An offset variable has its coefficient constrained to be 1.0 (McCullagh and Nelder 1999:206).

Let n_t be the number of doctorates awarded to men in all fields in year *t*. Our models are estimated as

$$\ln\mu_{it} = \delta_i + \ln n_t + \beta\mathbf{x}_{it}$$

where ln n_t is the offset variable. With a little algebra, this equation can be rewritten as

$$\ln(\mu_{it}/n_t = \delta_i + \beta\mathbf{x}_{it}.$$

In this way, the coefficients for the independent variables (when suitably transformed) can be interpreted as effects on the *percentage* of all men getting doctorates (rather than the absolute number) who got the degree in this field. (However, we also ascertained that our coefficients of interest are almost identical if this offset term is excluded.)

In addition to the dummy variables for field that make our models fixed-effects models, all models also include dummy variables for individual years. Adding dummy variables for years ensures that change over time in the popularity or availability of doctoral study, as well as inflation and changes in real salaries, are netted out to the extent that they affect all fields uniformly.

We used linear fixed-effects models (Allison 2005) to test the hypothesis that the lagged percentage female of those getting doctoral degrees in a field affects a field's starting academic salary. Such models are estimated in our pooled cross-sectional time-series data with year by field as units. They control for additive field and year effects, so that the coefficients of the sex composition of doctoral degree recipients on the later salaries of beginning assistant professors come from within-field changes in salaries as sex composition changes, rather than from cross-sectional variation in salaries that correlates with sex composition. In this way, if more female fields have always paid less, it will not contribute to a negative coefficient on the proportion female in the model because this is netted out by the fixed effect. However, if fields that feminized more than other fields saw a decline in the relative salaries of new assistant professors, it will show up in these coefficients.

RESULTS

We start by testing the hypotheses offered by the baseline demographic model. Hypothesis 1 predicts no desegregation of fields of doctoral degree receipt as more women got doctorates. Figure 2 shows the trend in segregation, using D.[5] Consistent with the hypothesis, over the entire period, the trend moved little. All values are between 35 and 39 on a 100-point scale. This finding is similar to that of Jacobs (1985, Table 7.2), who also used D and showed sporadic change up and down but no secular decrease in the level of segregation of doctoral

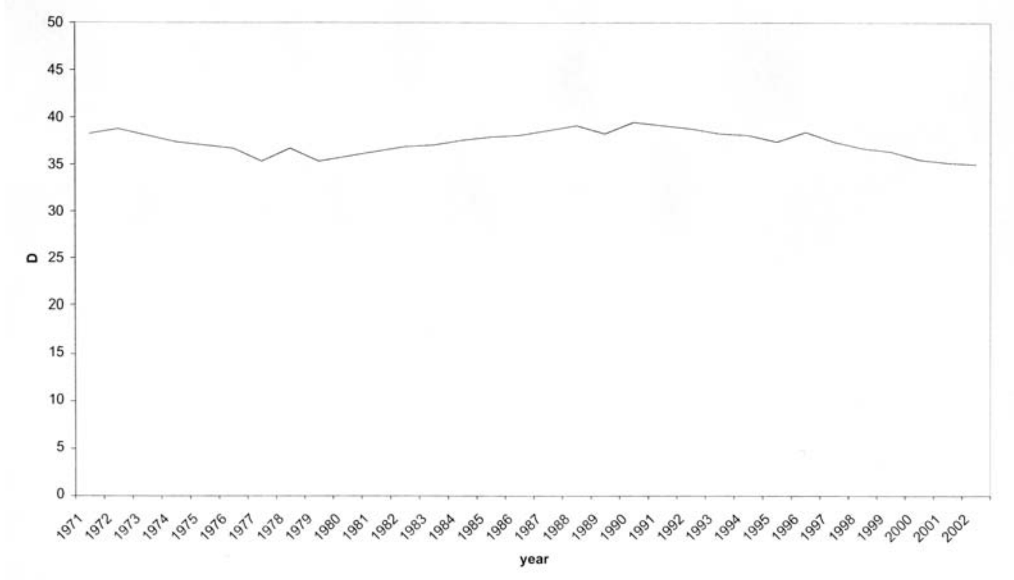

Figure 2. Index of Dissimilarity for the Sex Segregation of Fields of Doctoral Degree Recipients, 1971–2002

recipients between 1950 and 1980. Using 20 major categories, rather than the changing number of more detailed categories, Jacobs (1985) found that D was 32 in 1952 and 32 in 1980 as well. In a later analysis, which also used these broad categories, Jacobs (1995) found that segregation increased between 1980 and 1990, with D moving from 32 to 36.

Hypothesis 2, also from the demographic baseline model, states that while all fields will feminize to some extent as more women get doctorates, the relative sex composition of fields of doctoral receipt will change little. We examine this hypothesis in two ways. First, Figure 3 shows the scattergram associated with the zero-order correlation (Pearson *R*) between the percentage female in fields in 1971 and 2002 using only fields that were large enough to have granted at least 2,000 doctorates over the entire period. (The fields that were excluded comprised 7.6 percent of the persons who obtained doctorates over the years.) The correlation is .76, indicating a large degree of constancy in which fields contained relatively more women.[6] This trend is presented descriptively in Figures 4 and 5, which show the sex composition of selected large fields. While lines cross at some points, the overriding message is that the fields that were most male in the early period were also the most male in the later period (Figure 4) and those that were the most female in the early period were the most female in the later period (Figure 5).[7] It provides substantial support for the hypotheses from the baseline demographic model.

Hypothesis 3, from devaluation theory, states that the percentage female of those who get doctorates in a field will affect the number of men who get doctorates in the field several years later. The regression results presented in Table 1 speak to this question. Columns 1, 2, and 3 show three negative binomial fixed-effects models predicting male doctorates. All models contain dummies for fields and years, as well as the lagged natural log of the number of men who get bachelor's degrees in the field. Our interest is in the effect of lagged proportion female in the field. Since a squared term is always significant, we include it. Under each model, the table shows the point where the curve inflects from positive to negative. The first model contains dummy variables for year and field, the offset term, lagged proportion female, its square, and the control for lagged (ln) number of men obtaining baccalaureate degrees in the field. It shows a positive effect of proportion female on the number of male doctorates up to 24 percent female and a nega-

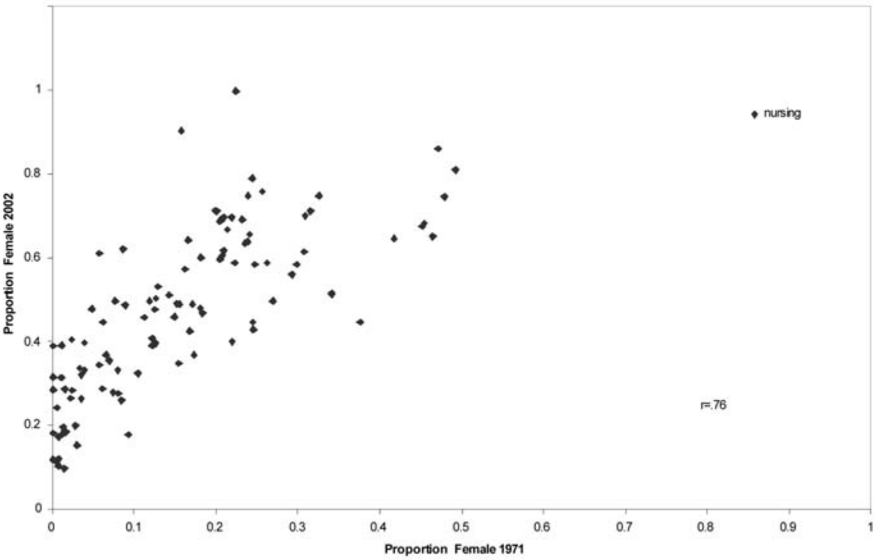

Figure 3. Correlation Between Percentage Female Among Doctorates Granted in 1971 and 2002

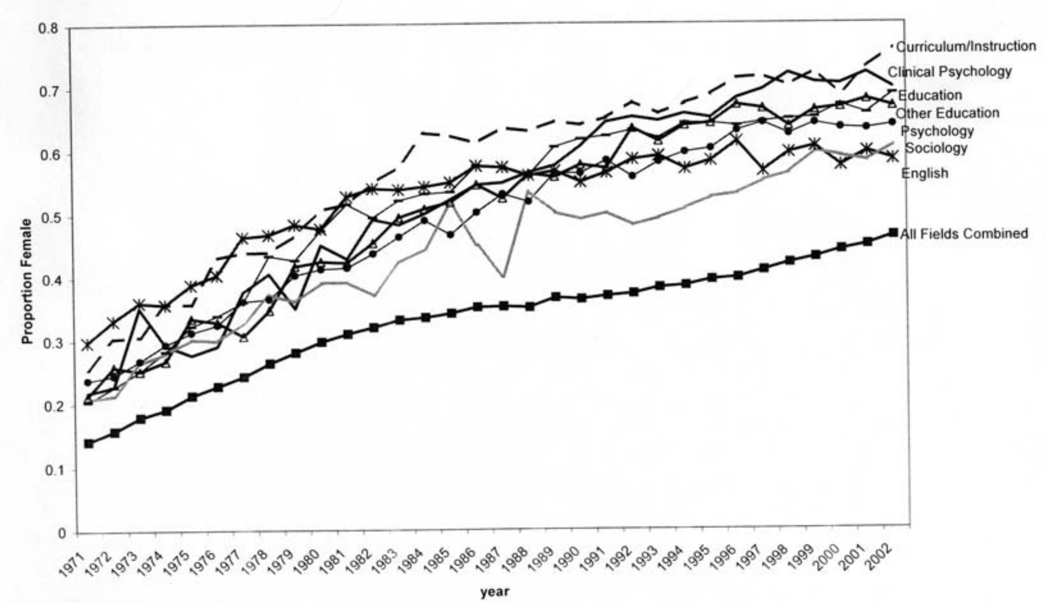

Figure 4. Trends in the Proportion Female in Selected Large Fields of Doctoral Degree Recipients (above the overall percentage female line)

tive effect thereafter. Thus, at any level higher than doctoral degree recipients being 24 percent female, further feminization deters men's later pursuit of doctoral degrees in the field. Any deterrent effect of the lagged percentage female in a field on men's entry may operate by discouraging men to major in the field at the bachelor's degree level. In this case, we would not want the lagged log of male bachelor's degrees controlled. In results not shown, we removed this variable. The new model has similar coefficients and inflec-

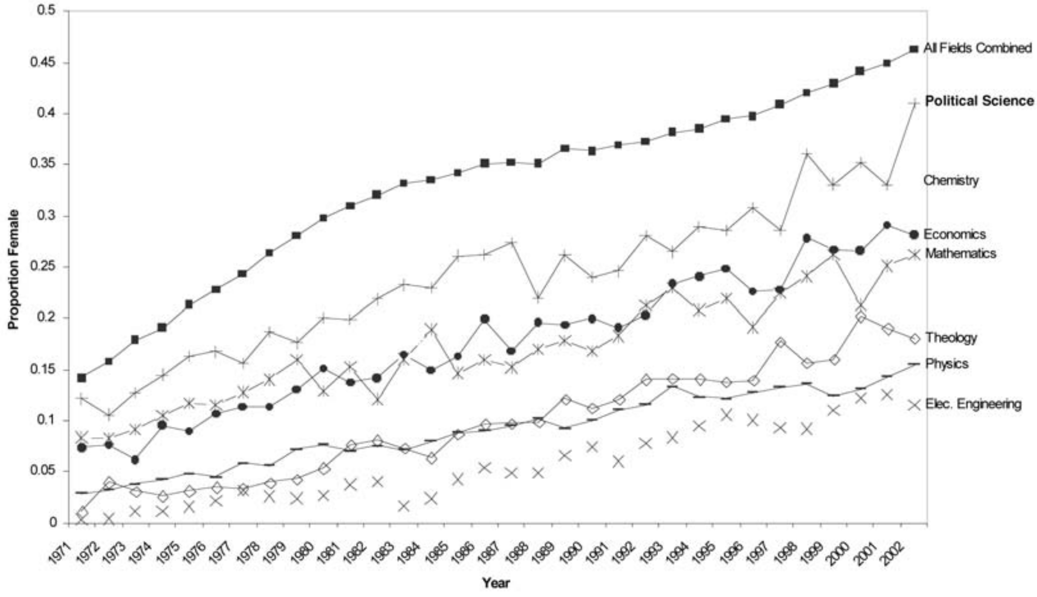

Figure 5. Trends in the Proportion Female in Selected Large Fields of Doctoral Degree Recipients (below the overall percentage female line)

tion point (.23).

One reason why women's entry to fields could deter men from getting degrees in those fields is simply that there is competition for slots in graduate programs. Suppose that in some fields, there were large increases in the number of female applicants but no changes in the number of male applicants. If the number of slots in doctoral programs in a given field in a given year is fixed by things other than the number of applicants (which is likely, since many doctoral programs fund students), then an infusion of women would reduce the number of men who obtain degrees simply because some of the women would beat men in the competition for slots. This situation would occur if admission was meritocratic and men and women were equally qualified. It would also occur if, within each field, the average qualifications of men and women differed, but the magnitude of that difference was constant over time. And it would occur if there was some unchanging amount of sex discrimination (against either sex, as long as the group that was discriminated against did not change) in admissions. To whatever extent the number of slots in each field is fixed for a given year and is not affected by how many people apply, this "competition effect" undoubtedly reduces the degrees awarded to men. If competition is the mechanism, however, the deterrent effect of percentage female on men's entrance should be immediate, rather than have a five-year lag. Thus, to remove this competition effect from our estimates of the effect of lagged proportion female, we include Model 2 of Table 1, which controls for contemporaneous proportion female and its square. We found an effect of contemporaneous percentage female in a field on the number of male doctorates that is negative above a proportion female of .15. While it is not monotonic (it is positive below .15), the negative effect in much of the range suggests that competition is part of the picture, as it must be if slots in graduate schools are limited. However, even with a control for contemporaneous percentage female, we still get a negative effect of lagged proportion female among doctoral recipients on the later number of men who obtain doctoral degrees in the field anywhere in the range above 35 percent female (see Table 1, Model 2).

Model 3 in Table 1 predicts (ln) number of men getting doctoral degrees in the field from lagged proportion female (and its square) of those getting doctoral degrees, the bachelor's

Table 1. Fixed-Effects Negative Binomial Regression Models Predicting the Number of Male or Female Doctorates (standard errors in parentheses)

	(1) Male Doctorates	(2) Male Doctorates	(3) Male Doctorates	(4) Female Doctorates	(5) Female Doctorates	(6) Female Doctorates
Lagged proportion female	1.510	0.764	1.770	3.197	-0.205	2.329
	(0.217)**	(0.214)**	(0.294)**	(0.253)**	(0.243)	(0.361)**
Lagged proportion female squared	-3.157	-1.098	-3.067	-4.217	-0.593	-3.659
	(0.207)**	(0.228)**	(0.302)**	(0.232)**	(0.239)*	(0.333)**
Lagged natural log of number of bachelor's degrees [a]	0.204	0.196	0.118	0.200	0.176	0.107
	(0.009)**	(0.008)**	(0.011)**	(0.009)**	(0.008)**	(0.011)**
Proportion female		1.074			7.716	
		(0.178)**			(0.226)**	
Squared proportion female		-3.477			-5.581	
		(0.205)**			(0.218)**	
Lagged natural log of new assistant professor salary			-0.097			-0.230
			(0.064)			(0.067)**
Constant	-5.106	-5.299	-5.188	-5.820	-7.271	-3.399
	(0.112)**	(0.178)**	(0.687)**	(0.183)**	(0.161)**	(.72)**
Inflection point where effect of lagged proportion female becomes negative	.24	.35	.29	.38	-.17	.32
Observations	4,411	4,395	2,378	4,411	4,395	2,378

*$p < .05$; **$p < .01$; two-tailed tests.

[a] The number of either male or female bachelor's degrees in the field, consistent with the dependent variable.

degree pipeline, and the lagged (ln) salary of new assistant professors. Note that the curvilinear effect of proportion female remains about the same when salary is controlled and is negative as proportion female increases everywhere above .29 (Table 1, Model 3). The conclusion is that salary is not the reason men eschew fields as they feminize (indeed, as is discussed later, lagged salary has no effect), but that feminization in and of itself deters the future entry of men above and beyond what is required by competition. Thus, our findings support Hypothesis 3 from the devaluation and tipping perspectives.

Model 3 in Table 1 also provides the test of Hypothesis 5 from the queuing perspective, which states that the lagged average salary of assistant professors encourages men to obtain doctoral degrees in the field (or, put another way, fields with declining relative salaries will lose men). The prediction is a positive effect, but we found no significant effect of the lagged average salary of new average assistant professors in a field on the number of men who get doctorates.[8]

Although not part of our hypotheses, Table 1 also shows parallel models predicting the number of female doctorates. Model 4, the female analog to Model 1, shows that women are also deterred from entry by too many women, but only above a proportion female of .38 (whereas men are deterred above .24). This finding implies that women moved away from more female fields over time, but not as much as men did.

Table 2 tests Hypothesis 4 from devalua-

Table 2. Fixed Effects Models Predicting the Average Salary of New Assistant Professors (standard errors in parentheses)

	(1)	(2)	(3)	(4)
	Log Average New Assistant Professor Salary	Log Average New Assistant Professor Salary	Average New Assistant Professor Salary	Average New Assistant Professor Salary
Lagged proportion female	0.026	-0.420	476.231	-10,766.704
	(0.033)	(0.065)**	(1,298.312)	(2,626.748)**
Squared lagged proportion female		0.513		12,946.211
		(0.066)**		(2,633.849)**
Constant	10.594	10.666	40,536.089	42,338.507
	(0.013)**	(0.016)**	(519.356)**	(633.536)**
Inflection point where effect of lagged proportion female becomes positive		.409		.416
Observations	2,378	2,378	2,378	2,378

*$p < .05$, **$p < .01$; two-tailed tests.

tion theory, that the feminization of those who obtain doctorates in the field negatively affects the later salaries of beginning assistant professors. We find a curvilinear effect. Regardless of whether or not we log the average beginning salary for assistant professors, at levels of lagged proportion female under .41 or .42, feminization reduces the average salaries of new assistant professors. If we use the model without logging, the predicted average salary of new assistant professors is reduced by $3,274, a reduction of 8 percent, from $39,765 to $36,491, as proportion female moves from 0 to .42. (Since salaries were in current dollars between 1978 and 1998, these averages can be thought of as in late 1980s dollars.) However, the findings also show that at levels above .42, proportion female increases the average salary, which is not what devaluation theory would predict. And fully 44 percent of the field-years had a proportion female above .42. Thus, there is only partial support for devaluation with regard to effects on pay; in close to half the distribution, the direction of the observed effect is opposite to the prediction. We are not certain what produced this anomalous finding. One possibility is related to the limitation of our data to an average salary in each field that combines men's and women's salaries. A standard practice in the devaluation literature has been to examine effects of sex composition on men' and women's salaries separately (e.g., England 1992). If men earn more than women within fields, as past studies have shown, then comparing the average salary in more heavily male fields to that in more female fields overstates the effect of sex composition on both male and female salaries in these fields. If the extent to which men outearn women is higher in some fields than in others, then this bias would be greater in some parts of the distribution than in others. Longitudinal data on average salaries, separately by sex and field, are needed to resolve this issue.

CONCLUSION

Some fields are tipping toward becoming all female. D shows no secular trend toward the desegregation of fields of doctoral degree receipt. We tested several theories from the literature on gender and occupations that offer predictions about how changes in sex composition are related to changing salaries and the entry of men. We found that much of the change in the sex composition of those who obtained doctorates in individual fields was dictated simply by the big increase in women relative to men who got doctorates—women went from being 14 percent to 46 percent of the doctorates received between 1971 and 2002. The strong correlation between the sex composition of fields in 1971 and 2002 (r = .76) and the lack of change in D's measure of sex segregation across the period suggest that much of the change in the sex composition of fields is explained by a simple demographic baseline model implying little change in how men and women (relative to each other) chose fields, conditional on getting a doctorate. This finding is consistent with the cross-cultural findings by Charles and Bradley (2002) that in many nations, the penetration of women into higher levels of education has increased without desegregating fields of study.

However, our regression analyses show that while the baseline demographic model explains most of what is going on, it does not tell quite the whole story. We found evidence that the feminization of those receiving doctorates at one point in time deters the later entry of men, as predicted by the devaluation perspective and Schelling's (1971, 1978) model of tipping. In the range higher than about one-quarter female, as women constitute a higher percentage of those who get doctorates in a field, men are discouraged from entering and getting doctorates in the field in subsequent years. Men are deterred from getting degrees in excess of what can be explained by simply being outcompeted by women applicants. Although we had no predictions in this regard, we also found that feminization discourages women's later entrance into fields.

We found no support for the queuing prediction that men's entry into fields is affected positively by salaries. Finally, we found some evidence for the devaluation prediction that feminization reduces salaries, but only in the range below a proportion female of .42 (the opposite effect obtains above this level). Given that an effect opposite to that predicted obtains in a good share of the range, we can only conclude that the prediction from the devaluation view regarding salaries has mixed support. To understand the source of the anomalous finding that feminization appears to lower salaries at low ranges but to increase salaries at high ranges of percentage female, we need longitudinal data on average salaries that provide separate averages for men and women. If the gender difference in salaries varies by field, this lack of disaggregation of averages by gender may have biased the results in unknown ways.

By contrast with the mixed support for the devaluation view's predictions about the effects of feminization on salaries, the tests of the devaluation and tipping views' predictions that women deter men's entry showed clear support. Although we did not have predictions about it, women's entrance was also deterred by feminization, although it took a higher percentage female to deter women's than men's entry into fields.

One limitation of our analysis is that we do not have measures of the changing characteristics of fields other than average salary and sex composition. Thus, it is possible that more female fields were decreasingly attractive to both men and women for some reason other than sex composition or salary and that this reason, rather than a response to sex composition, explains the movement of men (and women) away from fields as they feminized. For example, the biotech and digital revolutions have undoubtedly drawn people toward the excitement of fields that are relevant to them. We believe that by using a long longitudinal data series and fixed-effects models that control for unmeasured, unchanging characteristics of fields, we have presented a strong test of the queuing and devaluation-tipping effects on entry into fields. Nonetheless, since our fixed-effects models do not control for *changing* unmeasured differences among fields, we cannot eliminate the possibility that changes in some other characteristic of fields that are correlated with changes in sex composition are really driving the effect on the number of men. An advance in our analysis would require a longitudinal data series containing the number of men and women who obtained degrees in detailed fields that also contained measures of the changing characteristics of fields.

Assuming that our models are not biased by the limitation just discussed, how do we interpret men's increased avoidance of fields as they feminize? This avoidance may reflect a combination of pecuniary and nonpecuniary motives. Men may take the presence of women as a signal that the field will become low paying compared to fields with more men. However, our results contradict the idea that money is the whole story: There is no evidence that men change the academic fields they enter in response to *actual* changes in starting salaries, and feminization was found to deter men's entry even in a model that controlled for salary. This finding suggests that the nonpecuniary stigma for men of being in a field that is "too female" is the major part of what men try to avoid. Whatever the motive, men's woman-avoiding behavior contributes to tipping and makes it difficult to achieve an integrated equilibrium in academia. However, we should also remember that women's discouragement of men's entry is not the main cause of the feminization of fields. Simple demography (women's increased entry to all fields) is sufficient to explain most of it, even in the absence of either sex changing its relative preferences for fields. Indeed, another important topic for future research is why gender differences in the level of education attained have decreased much more dramatically than gender differences in the choice of fields.

NOTES

1. The metaphoric image of tipping is a see-saw. Once it goes far in one direction, it picks up speed and eventually tips all the way. A stringent definition of a tipping field is one in which the percentage of women is rising at an increasing rate, so that it will eventually become all female. We use the term to include such cases, but also in a less restrictive way to denote *fields that have become or have consistently been disproportionately female throughout the period and whose percentage of women continues to increase*. Under this looser definition, all fields except those that are still disproportionately male (i.e., more male than all doctorates combined) are tipping. When a disproportionately male field increases its percentage of women toward but not beyond the proportion of women of the overall system of doctorates, this change has an *integrative* effect, so we do not refer to such a field as tipping. Once a field has gone beyond the percentage female of the overall doctoral system, any continued increase in the percentage of women has a segregative effect.

2. The hypotheses that we test ignore possible discrimination in admissions to graduate school. Attiyeh and Attiyeh (1997) examined applications to and decisions in 48 leading graduate schools in five disciplines in the early 1990s and found no effect of gender (net of test scores, grade point average, national origin, and ethnicity) in biochemistry or mathematics, but some advantage for women in economics, English, and mechanical engineering. We know of no evidence for other periods or fields. Undoubtedly, there was discrimination against women in some earlier periods; whether or how far it extended into the post-1971 period that our data cover is unknown. We test hypotheses that assume that men and women choose the fields in which they pursue doctoral degrees, but that students' assumptions or knowledge about employers' discrimination may affect which fields students decide to pursue.

3. A table listing all the fields and how categories changed over time is available from the first author.

4. One limitation of the measures of sex composition is that they are not institution specific. Furthermore, changes in the extent of sex segregation by the prestige of an institution are not captured in our measured trends in the segregation index. This limitation applies to any segregation index we could use, given the available longitudinal data.

5. We chose D because it is self-weighting. However, this means that trends over time can be driven by disproportionate growth in more segregated or less segregated fields. It is thus useful to examine trends in D together

with its sized-standardized variant, SSD, which treats all fields as if they were the same size. Grusky and Charles (1998) devised A, the index of association, based on log-linear modeling. A, like D, is invariant to changes in the proportion of the two groups in the overall system, and because, like SSD, it weights fields equally, it is invariant to changes in the relative sizes of fields. (For debates on segregation indices, see Grusky and Charles 1998; Massey and Denton 1988; Watts 1998a, 1998b.) In results not shown, we calculated the other two indices. All three indices indicate declines in segregation in the 1970s. In the 1980s, D shows a slight increase, while A and SSD continue downward. All three show a quite modest or no decrease since 1990.

6. Nursing is an outlier in Figure 3. However, when we recomputed the correlation to exclude it, the correlation increased only from .76 to .77.

7. Of the largest 18 fields, which constituted 48 percent of the doctorates granted over the entire period, all but one field followed the basic pattern of little change in the rank order of percentage female of those in Figures 4 and 5. The exception is educational administration, which started as less female than all doctorates combined (9 percent female versus 14 percent female for the overall system), but was 62 percent female by the end of the period—more heavily female than doctorates as a whole (46 percent). Three fields not shown in the figures fit the overall pattern but are "bellwether" fields that have continually had a sex composition that is close to that of the overall system—biology, biochemistry, and history. One may expect that as more women get doctorates, the women who obtain them would include fewer pioneers (making choices unusual for women) and thus that women may select less male-intensive fields over time. However, the constancy in the rank order of fields by sex composition over time in Figures 4 and 5 casts doubt on this expectation. Moreover, in results not shown, we found that if fields are classified by their 1971 sex composition, women moved over time toward more male fields on average; this finding is also inconsistent with the idea that later women entrants are less "pioneering" in their choice of fields than are earlier entrants.

8. Salary also has a nonsignificant effect on the number of men getting doctorates if it is not logged. A nonsignificant effect is also found in a model that removes the lagged number of men getting bachelor's degrees in the field.

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