

**Why Are Some Academic Fields Tipping Toward Female?
The Sex Composition of U.S. Fields of Doctoral Degree
Receipt, 1971-1998**

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Abstract

Using data on the number of men and women receiving doctorates in all academic fields from 1971 to 1998, we examine changes in the sex composition of detailed fields. Women's proportion of those receiving doctorate degrees increased dramatically from 14% to 42%. All fields, including the most male-intensive fields, experienced an increase in their percent female, but the rank-order of fields in percent female changed little. Thus, in some fields well over half of doctorates go to women today. We then consider whether men avoid entering fields after they reach a certain percent female, thereby exacerbating the "tipping," such that fields that previously had a male majority become almost exclusively female. To test this, we use a negative binomial regression model with fixed effects. The model shows that the higher the percent female of those getting degrees in a field in a given year, the smaller the number of men that enter the field 4-7 years later. The pattern resembles Schelling's (1971, 1978) model of neighborhoods moving from a low to a very high percentage black because of whites' responses to the initial integrative moves by blacks. If men continue to react in this "woman-avoiding" way, it is unlikely that academia can move toward an integrated equilibrium, despite the fact that women's field choices are moving in a slightly non-traditional direction. We examine trends in segregation using three indices. While indices disagree on the trend for the 1980s, they all show a decline in segregation in the 1970s, but little if any decline by the 1990s. Men's avoidance of fields as they feminize may be impeding desegregation.

Why Are Some Academic Fields Tipping Towards Female? The Sex Composition of U.S. Fields of Doctoral Degree Receipt, 1971-1998

Consider the U.S. academic world in 1970. Although 43% of bachelor's degrees went to women, majors were quite sex-segregated, with a number of majors, especially education and some social sciences and humanities, numerically dominated by women (National Center for Education Statistics [NCES] 1973). Only 13% of doctoral degrees were awarded to women and doctorates granted in almost every field went overwhelmingly to men (NCES 1973). Soon a big gender shake-up was upon academia and the rest of the labor market. Between 1971 and 1998, women moved from being 14% to 42% of those receiving doctorates (National Center for Educational Statistics 1973, 2000). This was part of a larger change of the gender system involving women's increased continuity of employment, an organized women's movement, and a federal commitment to anti-discrimination laws. As more college women contemplated lifelong careers, some decided to get doctorates. The fields that have reached the highest percent female are those that were already disproportionately female in 1971, even though that still generally left men getting the vast majority of degrees. In some of these fields, well over half of degrees go to women now. For example, doctorates awarded in Communications went from 16% to 53% female between 1971 and 1998. In the same period, Educational Administration went from 13% to 79%, Industrial and Organizational Psychology from 20% to 58%, Microbiology from 18% to 45%, Psychology from 24% to 63%, Anthropology from 26% to 55%, Sociology from 21% to 56%, and English from 30% to 60% female. It appears that some fields are "tipping" toward all female.

In this paper, after reviewing past research, we describe patterns characterizing the changing sex composition of fields of doctorate study. We show trends in the percent female of

the 18 largest fields that account for about half of all degrees. We show that there is a very high correlation between the sex composition of fields at the beginning and end of the period.

We note the “tipping” of some fields. The term “tipping” invokes a metaphor. The image is of a see-saw. It can be perfectly balanced, but once it goes very far in one direction, it will pick up speed in that direction and eventually tip all the way. Following this, a stringent definition of a tipping field is one that is increasing its percent female at an increasing rate so that we believe the field will eventually become almost all female. We use the term to include such cases, but also in a less restrictive way to denote fields that are always or become disproportionately female, and continue to increase in percent female throughout the period observed. We don’t know for sure which fields will tip to almost 100% female. Since virtually all fields have increased their percent female with the large influx of women into the system, this means that all fields except those that are still disproportionately male are tipping under this looser definition. When a disproportionately male field increases its percent female toward but not beyond the proportion female of the overall system of doctorates, as in some sciences and mathematics, this change has an integrative effect, so we do not refer to these fields as tipping. Similarly, if the percent female in an initially disproportionately female field goes down, we do not refer to this as tipping toward male, since this too moves the system in the direction of integration. (If a field were to move from disproportionately female to disproportionately male, we would call this tipping toward male, but this has not occurred in any field of nonnegligible size.)

Our initial descriptive analysis suggests that one factor in tipping is simply the increase in the percent of doctorates going to women. Fields can be no more disproportionately female than previously, but now be majority female. We go on to consider whether men’s response to

increases in the percent female in fields exacerbates tipping. The reasoning behind this hypothesis is that men may find it stigmatizing to enter fields that are “too female.” The gender system are deeply asymmetric, with much greater stigma accruing to men for engaging in “female” activities than for women engaging in “male” activities. This flows in part from the cultural devaluation of women and, by association, with roles associated with women. Given this, we would expect men to avoid fields that become too female simply to avoid the stigma. Some research suggests that this devaluation also leads to lower rewards in “female” fields (England 1992), providing yet another motivation for men to avoid fields as they become feminized.

An example of this phenomenon in a completely different sphere, that of parents choosing what names to give their children, is illustrative. Lieberman et al. (2000) examine trends over the last century in parents naming their children androgynous names, like Kim or Leslie, that are given to either girls or boys. They find that androgynous names start like mutations, then increase in popularity for daughters. However, as the proportion of those given the name who are female rises, parents of boys stop using the name. Parents collectively act as if it is more stigmatizing to name a boy a name also used for girls than to name a girl a name also used for boys. This asymmetry means that names never stabilize as androgynous.

Our hypothesis that men’s responses to increased feminization may exacerbate tipping is also inspired by Schelling’s (1971, 1978) argument about how whites’ unwillingness to live in neighborhoods with “too many” African Americans can lead neighborhoods to tip toward all Black once they increase their percent Black above some threshold. He argues that initial increases in the percent black in a neighborhood puts the neighborhood over the comfort level for some whites, leading them to move out or not move in. This creates a further increase in the

percent black, 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' disinclination to live with blacks is greater than blacks' intolerance for whites. The process makes an integrated equilibrium impossible.

We will use a negative binomial regression model with fixed effects to test the hypothesis that an increase in the percent female of those getting doctorates in a field leads to a decrease in the number of men getting doctorates in the field about 5 years later. We find the hypothesized effect; it is evidence that men's response to "feminization" exacerbates tipping.

As the overall doctoral system feminizes, if tipping occurs as fields maintain a constant disproportion in their percent (or odds) female, it need not increase segregation. But if the proportion female in a field affects men's propensity to choose it, such that an increase in women's proportionate entry into a field will be followed by a decrease in men's choice of the field, as our regression analyses suggest, then this tipping process works against desegregation. It will increase segregation unless offset by enough of a trend toward women's field choices moving in a nontraditional direction. This line of reasoning made us interested in whether desegregation was occurring in doctoral degree field choices, or whether the male response to feminization might be enough to subvert any such trend. We use three indices, the index of dissimilarity (Duncan and Duncan 1955), the size-standardized index of dissimilarity, and an index based on log-linear models proposed by Grusky and Charles (1998) and report what they show about trends over time. Before presenting our empirical results we briefly review past research on the sex composition of academic fields.

PAST RESEARCH ON GENDER SEGREGATION OF ACADEMIC FIELDS

Men used to receive a preponderance of bachelor's, master's, professional, and doctoral degrees in the U.S. But, women have increased their representation at all levels. In 2001, 57% of Bachelor's, 58% of Master's degrees went to women, although women received just 46% of first professional degrees (NCES 2003). One might think that as women integrate higher levels of academic study, we would expect a desegregation of fields of study—that modern ideals of universalism would yield both forms of integration eventually. However, based on their cross-national study of gender segregation in higher education, Charles and Bradley (2002) conclude that “ideals of universalism do more to undermine vertical than horizontal segregation.” By vertical segregation they refer to each higher level of degree (2 year, 4 year, post-graduate) having fewer women. They find 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, the large increase of women's proportion in doctoral education is no indication that fields will integrate. Moreover, we should not be surprised to find some sex segregation of doctoral degrees in the U.S., since there is considerable segregation of undergraduate college majors (Jacobs 1985, 1989, 1995), and substantial segregation of occupations (Jacobs 1989, 2001).

Past discussions of segregation in the fields in which U.S. students earn undergraduate or graduate degrees focus largely on the “supply side” rather than on discriminatory processes of selection of students by institutions of higher education. While a century ago many universities did not admit women at all, in the post-1970 period students have generally been free to choose any undergraduate major once admitted to a university, as long as they have the prerequisite courses. For graduate study, students must be admitted to specific programs. Yet Cole (1986)

found that medical schools accepted male and female applicants at the same rates since World War II, although few women applied before the 1970s. We know of no research on whether doctoral programs discriminated for or against women, how this has changed, or how it has varied by field. We too will focus on a supply story, considering both its male and female side.

Writing on the segregation of academic fields focuses on explaining segregation in terms of women's, rather than men's, choices of sex-typical fields. The focus is on why more women don't choose or stay in natural sciences and other math-intensive fields, rather than on why more men don't choose social sciences, humanities, or education. But of course, both contribute equally to segregation. One stream of thinking focuses on women's different interests or skills, which various authors presume to come from innate differences, socialization consistent with cultural schemas about gender, or other aspects of social control that may start early and continue throughout the life course. There are gender differences in the occupations and academic majors that adolescents and young adults aspire to, and some differences in underlying values (Jacobs 1985, 1989, 2000; Marini and Brinton 1984; Marini and Greenberger 1978; Lueptow et al. 2001; Fiorentine 1988a, 1988b). Young men take more high school math courses and score slightly higher (about 15% of a standard deviation) on standardized math tests, and this leads more men to specialize in math-intensive majors and doctoral study (Xie and Shauman 2003; Hyde 1981; Eccles 1984; Linn and Hyde 1989; Tartre 1990; Friedman 1989; Wilson and Boldizar 1989; Kavrell and Petersen 1984). But early differences and socialization are not the whole story, since, as Jacobs (1989) points out, many young women who start out in "male" majors switch back to more traditional choices as college proceeds. Other social forces must push women back toward traditional fields. Despite this, during most of the 1970s and 1980s, women's choices of BA field became less traditional (Jacobs 1985, 1995a, 1995b). As Jacobs (1995a:91-92) states:

“(W)omen’s entry into male-dominated fields has been the principal cause of declines in sex segregation. . . . (T)he scarcity of men in . . . prominent female-dominated fields remains a significant obstacle to further gender integration. Men may avoid such fields because of the relatively low pay or because of the fields’ feminine connotations; more research is needed on this issue.”

There is only one previous study of trends in the segregation of fields of doctoral degree receipt. Jacobs (1985, Table 7.2) shows that there was sporadic change up and down but no secular decrease in the level of segregation of doctoral recipients between 1950 and 1980. Jacobs used the index of dissimilarity (Duncan and Duncan 1955), called *D*, which measures degree of segregation on a scale from 1 to 100, and (roughly speaking) indicates the percent of men or women would have to change fields to achieve a percent female in each field that is the same as the percent female of all fields combined. Using 20 major categories, rather than the changing number of more detailed categories, he shows that *D* was 32 in 1952 and 32 in 1980 as well. In a later analysis, Jacobs (1995) used the same categories and showed that segregation actually increased between 1980 and 1990, with *D* moving from 32 to 36. We know of no published analysis that extends these trends in segregation of doctoral fields past 1990. Nor, despite debates about the relative merits of indices of segregation, has anyone computed the trend in segregation using the log-linear based index proposed by Grusky and Charles (1998). We will use *D*, as well as a size-standardized version of *D*, and the index proposed by Grusky and Charles (1998). There are also no analyses to date that use quite detailed fields of study to examine trends in segregation; we will use a categorization into over 200 fields.

DATA

We use data published annually by the National Center for Education Statistics (NCES) (1973-2000) on the number of women and men receiving Bachelor's degrees and Doctorates in all fields of study from academic year 1970-71 to 1997-98. The system used by NCES to classify degrees into fields of study changed several times over the period. The most significant classification changes occurred in 1983 when the number of categories greatly increased. Some changes over time were simply minor changes in field names (for example, *agricultural business* became *agricultural business/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 used previously (for example, the new detailed categories of *animal breeding and genetics*, *animal health* and *animal nutrition* were put into the previous broader *animal science* category). In other cases, the new fields were put into the "other" category for the relevant broader field (for example, many of the more detailed agricultural business fields that appear in later years were classified under *other agricultural fields*). The "other" category, which appears for all of the broadly defined fields, is what changes most over time, as more detailed and extraneous fields that cannot be classified elsewhere were added to that category. Finally, a few fields disappear altogether over time (*remedial education*, *African languages*, *Indic languages*, and two interdisciplinary fields), and *Women's Studies* does not appear in earlier years. From these classifications, we constructed a categorization system of 260 fields for the 28 year period.¹ We created a data set with field-year as the unit of analysis for all academic years beginning with 1970-1971 and through 1997-98. (We will refer to academic years in terms of the later year since degrees are generally granted in the spring.) Our descriptive statistics will show the trends in the sex composition of doctoral degree recipients as a whole,

and the 18 largest fields, which, combined, contain 48% of all doctorates given across the 28 years. (In results not shown, we have used a log-linear model to show that year interacts with the sex-field relationship, suggesting the relevance of the hypothesis to be tested.)

REGRESSION MODELS

To test the hypothesis that men increasingly avoid fields as their percent female rises, and thereby exacerbate tipping, we use a negative binomial, fixed-effects regression model (Cameron and Trivedi 1998, Allison and Waterman 2002). The independent variable is the lagged proportion female of those getting doctorates in the field; the dependent variable is the (natural log of the) number of men getting doctorates in the field about 5 years later. We also report on parallel models for women. 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 a expected value μ_{it} and a variance given by $\mu_{it}(1+\alpha\mu_{it})$ where α is an overdispersion parameter. (When $\alpha=0$, the distribution is Poisson with 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. It is much less restrictive than the Poisson distribution, which does not fit these data well due to overdispersion.

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

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

where \mathbf{x}_{it} is a vector of explanatory variables that vary with time and across fields and α_i is an intercept specific to each field. The two time-varying explanatory variables we include are both lagged approximately five years behind the dependent variable. Ehrenberg (1992) shows that the median time enrolled to receiving a doctorate varied from 5 to 7 years in the 1970s and 1980s, so

¹ A table listing all fields and how categories changed over time is available upon request.

we wanted a lag of approximately this length. To avoid large year-to-year fluctuations in small fields, we averaged the percent female getting degrees in the field 4, 5, 6, and 7 years before the year in question and use this (unweighted) average as the independent variable of interest. The average year of the lag is 5.5 (for simplicity we refer to this as 5 years before). We also experimented with slightly longer lags, but it changed the results little. The idea is that men form their idea of the gender label of a field from observing who the young professors, teaching assistants, and research assistants in the field are while they are in college making choices that eventually lead to choices about what field to apply to graduate school in. Because fields up to 7 years before were averaged to get the lagged independent variable of interest, our regressions begin with 1978 (because for this year the lagged variable comes from 1971-1977 data). We also control for the number of men getting baccalaureate degrees in this field (exactly) five years earlier to control for the available “pipeline” of people with a major in the area. We do not average several years to get the lagged value of this variable, as we do for proportion female, since most fields have fairly large numbers of baccalaureate degrees given each year, and the numbers do not fluctuate drastically from year to year. In models predicting the number of women getting doctorates, this control is for number of women getting baccalaureate degrees in the field five years earlier.

The μ term is what makes this a fixed-effects model, implicitly controlling for all stable characteristics of each field. For example, if some fields are always larger than others because they are attractive to students, this is controlled. Similarly, if a field has an unmeasured characteristic, such as requiring very high math GRE scores that would eliminate more women than men, and this has a relatively constant effect on its sex composition, this is also implicitly controlled. If a field has an enduring social label as a “man’s” or “woman’s” domain and this

affects which gender has more social support for choosing the field as a career, this is controlled. To get an intuitive understanding of what fixed-effects models do it is helpful to think of them as calculating, for each field, the extent to which changes over time in percent female were followed by later changes in the number of men receiving doctorates; then the magnitude of these effects are averaged across fields. While we can never be sure we are picking up only causal effects outside true experiments, we believe that fixed-effects models remove more omitted-variable bias than other available options.

We estimate the model with conventional software for negative binomial regression, directly estimating the β_j 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) have proven that this method is valid for Poisson regression. Allison and Waterman (2002) have demonstrated by simulation that this result also extends to negative binomial regression models. However, they also found that conventional standard error estimates 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 implement that correction here.

The models we estimate also include an “offset” term to control for the total number of doctorates awarded to men (or women) in any given year. For example, let n_t be the number of doctorates awarded to males in all fields in year t . Our models will be formulated as

$$\ln \pi_{it} = \beta_i + \ln n_t + \beta \mathbf{x}_{it}$$

where $\ln n_t$ is the offset variable whose coefficient is constrained to be 1.0. 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 have also ascertained that our coefficients of interest are almost identical if this offset term is excluded.) All regression models contain dummies for fields and a cubic function of calendar year (that is, time, its square, and its cube are entered), and control for the log of number of bachelors degrees received in the field by the sex to which the dependent variable refers, lagged five years. To keep results from being affected unduly by large sex composition oscillations in tiny fields, all models also deleted any fields that did not give at least 100 doctorates in total between 1971 and 1998. We deleted from our analyses any fields that had 0 degrees granted for any year. Thus, we were left with 202 fields and a dataset with 5656 observations (28 years times 202 fields). However, since, as described above, we use averages from 4-7 years previous for lagged proportion female, this means that the first 7 years cannot be used in our analyses (except to create lagged variables). Thus, our analysis is on 21 years, yielding 4049 observations (21 years times 260 fields). These cases contain about 99% of the persons, since the fields dropped were very small.

MEASURES OF SEGREGATION

We examine the trends in sex segregation of fields of doctoral study across the period. The most common measure used in studying sex segregation is D , the index of dissimilarity (Duncan and Duncan 1955). The interpretation of D is often explained in a “shorthand” way as the percent of women (men) who would have to “trade” fields with a man (woman) for both sexes to be represented in all fields in proportion to their representation in the overall system. If women got 14% of all doctorates, as they did in 1971, then women would have to be 14% of the degrees in a field to be proportionately represented; if women constitute 42% of all doctoral degrees, as they did in 1998; proportionate representation requires that they be 42% in each field. This shorthand interpretation is somewhat misleading, however, because it only describes the

numerator of D . More precisely, the numerator is the number of “trades” of women and men required for evenness as described above, and the denominator is the maximum number of such integrative “trades” possible starting from complete segregation. The denominator is maximized when each group is 50% of the population. D is implicitly weighted; big fields contribute more. This is appropriate if our interest is in the segregation experienced by the average person. However, this self-weighting of D also means that trends over time can be driven by disproportionate growth in more or less segregated fields, even in the absence of changes in the sex composition of any fields. It can thus be useful to examine trends in D together with its sized-standardized variant, SSD . SSD has the same interpretation, but is calculated so as to treat all fields as if they were the same size. More recently, Grusky and Charles (1998) have devised A , an index based on log-linear modeling. They prefer it to SSD because it is invariant to changes in the proportion of the two groups in the overall system (D shares this invariance with their measure). It is also invariant to changes in the relative sizes of fields. Like SSD , A , equally “weights” fields regardless of their size (this is how it achieves invariance to relative sizes of fields). Our goal here is not to debate the relative merits of these indices, but to see if there is a robust conclusion about trends in segregation. (For debates on segregation indices, see Grusky and Charles 1995; Watts 1995a, 1995b; Massey and Denton 1985.)

THE CHANGING SEX COMPOSITION OF FIELDS OF STUDY

We start by offering a descriptive portrait of the changes in sex composition of doctoral degrees as a whole and of the largest 18 fields in our data which, taken together, contain almost half (48%) of all degrees given across the period. Figure 1 shows the absolute number of men and women getting degrees each year. Men got about 27,000 doctoral degrees a year in the early 1970s, reduced their annual numbers somewhat in the 1980s, and returned in the 1990s to

about 27,000 again. Thus, the net trend is flat. Women's numbers have increased continually, moving from just under 5,000/year to about 20,000 per year. Thus, all the net growth has come from women.

Our main interest, however, is in the sex composition of fields of study. While we know that, given the growth of women in the overall system, all fields are likely to have seen increases, we were curious whether those fields that had relatively more women in the early period tended to have more in the later period as well. Figure 2 shows the scattergram associated with the zero-order correlation (Pearson R) between fields' 1971 and 1998 percent female, using only those fields large enough to have given at least 1,000 doctorates over the whole period. (The fields excluded comprise 3.1% of the doctorates.) The correlation is .85, indicating a large degree of constancy in which fields contain relatively more women.

Figures 3 through 6 reiterate this theme, showing trends in the sex composition of selected specific fields. Together these figures cover the 18 largest fields that, when taken together, accounted for 48% of the doctorates over the period. Figure 3 shows the overall percent female of those receiving doctorates compared with the percent in those of the largest 18 fields that were disproportionately female throughout the period. They include clinical psychology, three education fields, psychology, English, and sociology. Figure 4 shows fields that were disproportionately male. In order, from the most male dominated to closest to integrated, they are electronics and electrical engineering, physics, theology and divinity, mathematics, economics, chemistry, and political science. What is striking, however, is how, while every field saw a dramatic increase in women's representation, the rank order of the fields in their sex composition changes little. Figure 5 shows 3 "bell weather" fields that, throughout the period, have had a sex composition very close to that of the overall system—biology,

biochemistry, and history. Finally, Figure 6 shows an exception to the general pattern—the large field of Educational Administration (the degree people often get to become principals or superintendents). This field started disproportionately male (about 10%), but by the end of the period was about 60% female, much more heavily female than doctorates as a whole (42%). Overall, the picture one gets is of women increasing in all fields, but of considerably constancy in which fields were more and less female-intensive.

We see that, using our definition of “tipping” as including any field that moves into the disproportionately female range (whether it started there or not) and is continuously increasing its percent female, all the fields in Figure 3, plus Educational Administration, are “tipping.” But this descriptive portrait does not clarify how much tipping arises because of women’s choices or men’s movement away from fields as more women enter. Our regression analysis below is designed to examine this question.

THE ROLE OF MEN’S BEHAVIOR IN TIPPING AND CONTINUED SEGREGATION

Do men reduce their entry into fields if they get “too female”? Table 1 presents regression results to answer this. The first row shows a negative effect of a field’s percent female on the number of men getting degrees in the field 5 years later. The next row shows that a nonlinear specification of this effect is needed since the square of percent female has a significant coefficient. (We tested for higher order effects, but the cube of percent female had no significant effect.) Calculations from the coefficients show that when the percent female of fields is under 23%, additional increments do nothing to deter men’s entry; however, beyond this, as fields get more heavily female, men are deterred from entering more and more. This is depicted in Figure 7.

We did a number of analyses to assess the robustness of the conclusion that a higher percent female in fields deters men's entry. We examined whether the effects for men hold up within each of the two halves of the period. The coefficients differ by period (Table 1), with the effect stronger in the earlier period (see Figure 8), but women's presence deters male entry throughout much of the range in both years. In the early period, at any percent female above 15%, additional feminization deters men's entrance, whereas in the period past 1988, this inflection point in the curve occurs at 38%. Of course, all fields increased their percent female substantially by the later period, so men would have been much more restricted in field choices had they been as deterred by as small a proportion of women in the later period as the earlier period. Still, the change in coefficients does suggest that as higher proportions of women become the norm, men get used to the idea of being in a field with somewhat more women, and successive cohorts of men are less deterred by a given level of percent female. Yet, it appears that they are always deterred if fields are disproportionately female relative to the system of doctoral fields.

We were also interested in whether the relationship would look different in math/science fields which typically admit only students with extensive undergraduate mathematics training. (All of mathematics, engineering, computer science, and the natural sciences were classified as "math/science," as were economics, and statistical or IT specialties within business or education.) As Table 1 and Figure 9 show, for these fields, there was a linear and negative effect of percent female on the number of men in the field 5 years later, whereas in all other fields the effect was nonlinear. Still, for both math-intensive and other fields, the effect is negative in most of the range (see Figure 9).

In results not shown, we also estimated the effects for the whole sample excluding the control for lagged number of men or women getting bachelor's degrees. It changed the shape of the percent female effects very little. We also experimented with expressing percent female in dummy variables rather than as a quadratic and squared term. Results were roughly consistent with the shape obtained here. In addition, we tried running our models with a slightly different dependent variable: number of men (women) getting degrees in a field as a proportion of all men (women) getting PhDs that year. (The offset term was eliminated for this run.) Again, the shape was qualitatively similar. We also ran a linear fixed-effect model, rather than the negative binomial. Here too the shape of the curve depicting the effect of percent female was qualitatively similar. (We first ran random effects models, but a Hausman test indicated that a fixed effect model was needed. We have not utilized a Hausman-type test on our negative binomial results, since such a test has not been developed in the literature.) Overall, the findings seem fairly robust in indicating that, above a certain level, the entrance of more women into a field makes men less likely to enter.

The estimated effect of women's proportion on men's entrance can be interpreted in a number of ways. We believe that men's avoidance to more female fields reflects a combination of pecuniary and nonpecuniary motives. Men may take the presence of women as a signal that the field is or will become low paying compared to fields with more males. On the nonpecuniary side, men probably avoid fields that are "too female" because it is stigmatizing for men in our culture to be in an activity, field, or job associated with women. We cannot assess the relative strength of the nonpecuniary and pecuniary motivation with these data, but we are relatively confident that, whatever the motivation, the sheer presence of women deters men's entrance.

If it is correct that men are moving away from fields as women enter in moderate numbers, then we should see a higher proportion of the men getting doctorates choosing traditionally male fields. Thus, as a further check on the account offered here we examined the average percent female experienced by the men getting doctorates in each year, classifying fields by their 1971 sex composition. This was done by computing a weighted average of fields' 1971 percent female, weighting fields by the number of men getting doctorates in the given year. When these averages are arrayed by year, the average percent female changes only as a function of the weights, which means they change only as a function of changes in which fields men's choices were concentrated in, not as a function of changes in the sex composition of given fields (the latter is affected by the proportion of the overall system that is female). Figure 11 presents the results of such a computation for both men and women. Focusing on the men's curve, we see that, as predicted by the dynamic implications of our regression analysis, men moved in a slightly traditional direction across the years. Whereas in 1971, the average man getting a doctorate was in a field that was 13% female, by 1998, the men were getting doctorates in fields that averaged only 10% female in 1971.² This is consistent with the idea that, as women entered fields that started out disproportionately female and then got above the threshold engendering the "avoidance" response, men's choices moved away from these fields toward initially more male fields. Thus, in moving away from fields as they became more female, and increasingly choosing more traditionally male fields, men's responses did nothing to aid integration, and instead contributed to continued segregation. While the magnitude of men's move away from more female fields was small, men would have had to move in the opposite direction, toward

² A downward trend is also observed if we make the same calculation but classify fields by their 1998 sex composition. However, if the percent female of the fields men (or women) experienced each year is calculated at their current (changing) sex composition, then the curve trends upward for both men and women because the

disproportionately female fields to contribute to integration. Instead their moves contributed to segregation, so segregation would have increased if women had not moved toward more male fields.

Moreover, if, as our regression results suggest, men avoid fields more the more female they become, this contributes not only toward continued segregation but to fields tipping to all female. As fields increase their percent female, fewer men enter them, which further increases their percent female, which leads even fewer men to enter. Absent some countervailing force, this will eventually move any field above the inflection point of the curve to all female. Thus, the regression results suggest that complete tipping will ultimately occur in some of these fields, although this is a prediction beyond the range of our data (there were no 100% female fields by 1998). The one thing in the analysis that casts doubt on the inevitability of complete tipping is the upward movement of the inflection point above which increments of percent female deter male entry (Table 1 and Figure 8). This suggests the following speculation: Fields that experienced a large influx of women *before* men's threshold of tolerance moved up will be those that will tip to almost all female. In other fields, the cross-cohort increases in men's tolerance for higher levels of women may precede large influxes of women, and in these cases tipping may be stopped.

THE ROLE OF WOMEN'S BEHAVIOR IN TIPPING AND INTEGRATION

We have seen that men's behavior did nothing to move the system in the direction of integration, and promoted tipping of some fields. What about women's behavior? Did it promote integration or segregation? Did it contribute toward tipping? Understanding women's role is trickier than understanding men's, because, whereas men's behavior promoted both

movement of either group toward fields initially more male is smaller than the increase in percent female in all fields resulting from the large increase in percent female of those receiving doctorates.

segregation and tipping, women's behavior encouraged both *integration* and tipping. (This is paradoxical since tipping is inherently segregative.)

Let us look at the results of parallel analyses for women to those we performed for men. Referring back to Figure 11, we see the trend in the fields women chose on average, when fields are scored by their 1971 sex composition. The average woman getting a PhD in 1971 was in a field that was 24% female, but by the end of the period the average woman was getting a degree in a field that in 1971 had been 20% female. While this is only a small change, it shows that women moved modestly in a less traditional direction over the period, toward fields that were initially more male. This is consistent with the increasing representation of women in the natural sciences, other math-intensive fields, and all male-dominated fields that we saw in Figure 4. These fields were disproportionately male in the whole period. However, women's increased representation in them was an integrative force.

The regression results (Table 1, Figure 7) present an image of women, like men, avoiding fields if they get too female. However, compared to men, women have a higher threshold for the level of feminization they tolerate before it adversely affects their entry into fields. Looking back at Table 1, the third and fourth rows predict the number of women getting doctorates in a field in a given year from the number of women getting Bachelor's in the field 5 years later and the proportion female among those getting doctorates 5 years later. If proportion female is entered linearly, it has a negative effect, as for men. As for men, the square of percent female has a significant negative effect as well. (The cubed term was nonsignificant, as for men.) Computations from the coefficients of the quadratic model show that the curve predicting women's entry differs from that for men, particularly at low levels of percent female. At levels of percent female under 32%, increases make women *more* likely to enter the field 5 years later.

This suggests that women feel more comfortable going into a field when there is a critical mass of other women. But beyond approximately one-third women, additional increments of percent female deter women's entry as they did men's. Thus, the effects of sex composition differ for men and women in the sense that men start being repelled from fields at much lower levels of percent female and the deterrent is stronger for men than for women. But, at some point, women's presence deters women's as well as men's entrance.

So far the results suggest that all of women's behavior is pushing in a nontraditional direction—on average they moved toward more traditionally male fields across the thirty years, and the regression results suggest that past some threshold, when the percent female in a field gets too high, they move to more male fields. This seems at first glance to suggest that women's behavior has moved the system toward integration and contributes little to tipping. While this is true of the direction of change in women's field choice, there is a huge countervailing force that must be acknowledged and is “held constant” that thus not shown in the regressions--the dramatic increase in the number of women (relative to men) getting doctoral degrees. Thus, while women moved their field choices in a slightly more male direction over the years, the huge increase in the number of women getting doctorates, combined with the still substantially (though decreasingly) traditional tilt of their choices, sent huge infusions of women into fields that were already disproportionately female. Even if this had not scared any men away, and even if men weren't competing with these women for a fixed number of slots in doctoral programs, these infusions of women in disproportionately female fields would have contributed to tipping if we define it simply as an increase in the percent female of a field that is already disproportionately female. In this sense, women's behavior contributed to tipping, even while it was contributing to greater integration of fields.

Thinking along these lines made us wonder if women's entry to fields could be deterring men from getting degrees by a mechanism much simpler than men's tendency to shy away from fields if they are "too female"—the mechanism of competition. Suppose that in some fields in the humanities and social sciences, there were large increases in the numbers of female applicants as more women aspired to doctoral degrees, but no changes in 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 simply because some of the women would beat men out in the competition for slots. This then would contribute to tipping of fields even if men weren't avoiding women. Imagine that men and women applicants to each field were equally qualified, but some fields experienced much more of a "shock" of an increase in female applicants than others. If admission was simply meritocratic, this would lead to fewer males. The same result would occur if, within each field, average qualifications of men and women differed, and the magnitude of that difference were constant over time. It would also hold if there was some unchanging amount of sex discrimination (against either sex, as long as which group is discriminated against didn't change) in admissions. To whatever extent the number of slots in each field is fixed for a given year and not affected by how many people apply, this "competition effect" is undoubtedly part of the explanation for the tipping of some fields, and its genesis is in the increase in women's applications.

Given this inevitability of competition, we initially worried that our regression results in Table 1 might reflect nothing but this effect of women's entry increasing competition in disproportionately female fields. If competition is the mechanism, however, the deterrent effect of percent female on men's entrance should be immediate rather than have a five year lag and

should be linear. As we have seen, the effects are generally not linear and are lagged. Still, given strong serial correlation, we were concerned that contemporaneous competition, which undoubtedly exists, might contribute to the findings for men in Table 1. Thus, to assess how much men are moving away from fields above and beyond what can be explained by encountering increased competition, in results not shown, we ran models like those in the first rows of Table 1, but with the effect of contemporaneous percent female controlled. We did find a strong negative effect of contemporaneous percent female in a field on the number of male doctorates, suggesting that competition is part of the picture, as it must be if slots are limited. However, even with a control for contemporaneous percent female, as Figure 10 shows, we still get a similar shape for the effect of the percent female in one year on the number of male doctorates in a field five years later. In other results not shown, we put in the percent female in the present and each lagged year up to 8 years in the same model. In that analysis, we saw a large contemporaneous effect, which probably reflects competition. However, the lagged effects get bigger for successively longer lags. This is not consistent with the effect being *all* contemporaneous competition from women's increased application, but is consistent with potential cohorts of entering men being affected in their choices by how female the population in the field is, as we hypothesize.

Let us summarize our view of the role of women's behavior in trends in segregation and tipping. Women's field choices have moved toward fields that in 1971 were disproportionately male fields, and women, like men, have a tendency to avoid fields if they become too female. Thus, women's field choices contribute toward decreased segregation. However, women continue to choose fields that are disproportionately female, and the sheer volume of women entering doctoral programs has increased much more than for men. This has led to large

infusions of women aimed disproportionately at fields already more female than the average field. In this way, women's behavior has contributed toward tipping. To the extent that slots in fields are fixed for any given year, infusions of female applicants will also contribute to tipping by increasing the number of male applicants who are denied admission due to the new competition. In sum, as odd as it sounds, women's behavior contributes both to tipping and integration.

TRENDS IN SEGREGATION

Our analysis above suggests that men's behavior contributes to the "tipping" of fields toward female, consistent with Schelling's thesis. As with residential racial segregation, one of the implications of this model is that an integrated equilibrium is unlikely to occur. Men's behavior is working against integration, even while women's behavior is working toward it. Given that, we wondered what the net result of these and other factors on trends in segregation has been. While it is beyond our scope to analyze the causes of any trends we find, we set out to map trends in segregation using three indices, D , size-standardized D (SSD), and A , based on log-linear models, proposed by Grusky and Charles (1998). These trends are presented in Figure 12. (Note that A has a different metric than D and SSD. D and SSD range from 0 to 100, which represents maximum segregation; A ranges from 0 to infinity.) While A and SSD differ in that A is invariant to changes in the sex composition of the entire doctoral system, while SSD is not, it is nonetheless striking that they give an extremely similar trend line. D , in contrast, shows quite a distinct trend. A and SSD are similar in both weighting cases equally, while larger fields count more in D . On the other hand, D and A have in common that they are invariant to transformation in the sex ratio of the overall system (Grusky and Charles 1998), and we might think this important for cross-year comparisons since the doctoral system has feminized from 12% to 42%

female. However, since it is A and SSD that show a similar trend, this suggests that, in this case, it is their common characteristic of weighting cases equally that is driving the similarity.

Unfortunately for our substantive interests, the three indices do not tell a simple and consistent story about the trends. However, some conclusions are possible. All three indices show a decline in segregation in the 1970s. Similarly, all three show little change in segregation in the 1990s (though A still shows a bit of decline). This suggests a stalling of desegregation. This is consistent with the desegregative force on men's response to women's entry offsetting the integrative force of women's move toward slightly more nontraditional fields. Where the indices disagree the most is about the trend in the 1980s. D actually shows an increase in segregation, while SSD and A show decrease. Perhaps some very segregated fields had disproportionate growth during this period, or a few very large, tipping fields became more segregated. Explaining this divergence is beyond our scope. We simply note that earlier trends to desegregation appear to have reversed (if we believe D) or at least stalled (if we use SSD or A).

DISCUSSION

Some academic fields are tipping toward all female and the desegregation of fields has slowed or stalled in the 1990s. In this paper we have considered the role of changes in both women's and men's behavior in contributing to trends in segregation and tipping.

Women's behavior has had ironic effects. Because women's field choices are still more "female" than men's, and women's numbers have increased massively, the infusion of women into some fields in the social and behavioral sciences and humanities has contributed to tipping. This is true despite the fact that women's field choices have moved slightly toward initially more male fields. In this, women have contributed to integration. But, actually what is striking is how little the field choices of either men or women have changed, conditional on choosing to get a doctorate.

Both of moved in the direction of initially more male fields, but only slightly so. It is consistent with Charles and Bradley's (2002) cross-national observation that lower levels of vertical segregation (whether men get more higher degrees than women) tell us little about whether a system will have a low level of segregation of fields.

While women's behavior may have contributed only mildly to integration, men's behavior has not been integrative in the least, but has contributed toward segregation and tipping. One way men's behavior contributes toward tipping is in their increasing avoidance of fields as they become more feminized. The dynamic implications of our regression analyses suggest a pattern as follows: The entrance of women into a field increases its percent female, and at least for fields already above some threshold, this deters men's entrance into the fields. The threshold above which increments of percent female deterred men averaged 15% in the early period and 38% in the later half of the period. This is interesting, since women were 14% of those getting doctorates in 1971 and 42% in 1998, so it appears that it is somewhere in the neighborhood of when fields become more female than average for the period that men's avoidance reaction is activated. This failure of men to enter fields increases their percent female even more. But this in turn makes fields even less attractive to men of the next cohort. Unless the increased tolerance of successive cohorts of men for more female fields intervenes soon enough, the outcome may be "tipping" to close to all female for some fields. This is similar to the process described by Schelling (1971, 1978) in his discussion of Whites' response to an increasing proportion of African Americans in a neighborhood. Whites can avoid Blacks by leaving the neighborhood or by failing to move in. We only have the analog of the latter response here because ours is a "flow" rather than "stock" measure of sex composition; we look only at those who have just entered the field by getting doctorates rather than all those in a field. We doubt that men who have already invested in a

doctorate and obtained a job will leave it because the number of women gets too high, although Reskin and Roos (1990) argue that this happens in some occupations, especially those requiring little training. However, a tipping effect can occur even if no men leave a field in response to women—nonentrance is sufficient to make fields tip, although change coming through successive cohorts' disinclination to enter affects the overall proportion of the academic field very slowly. As long as men respond in this way, it is difficult to imagine how an integrated equilibrium can be reached.

What is it about women's presence that scares men from entering fields? We cannot tell from these data. We suspect that both pecuniary and nonpecuniary motives are involved. We envision students who aspire to get a doctorate making choices about what field to apply in based on their own college major (some fields only accept students in that field or, in the case of math-intensive fields, in a field providing similar mathematics preparation) and their occupational aspirations. But these choices of majors and occupational aspirations are themselves shaped both by what is seen as socially acceptable for a person of one's own sex, and by the earning potential of the field. If young men taking courses see women as graduate students, teaching assistants, and young faculty members, they may conclude that this is a "female field" and avoid applying for graduate study. This may be because they anticipate that if fields become too female their pay will go down, as claimed by advocates of comparable worth (England 1992). Bellas (1994) has shown that academic salaries are lower in fields with a higher proportion female, even net of numerous individual controls and a measure of what people with doctorates in the field can make outside academia. However, we know of no dynamic evidence of relative salaries in academic fields changing in response to changes in sex composition (we hope to examine this in future research). On the nonmonetary front, men may simply find it socially stigmatizing to be in fields

with too many women. This is consistent with the notion that masculinity is socially constructed in terms of rejecting whatever is seen as female (Williams 1993). Whatever the reason that men move away from fields as women enter them, it makes it difficult to achieve a stable, integrated equilibrium in academia.

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Table 1

Fixed-Effects Negative Binomial Regression Models

Dependent Variable	Independent Variables ^a		
	Prop. Female	Prop. Female Squared	Log of Number of Bachelors Degrees ^b
Male Doctorates	-1.51** (.14)		.189** (.011)
Male Doctorates	1.76** (.26)	-3.90** (.26)	.184** (.011)
Female Doctorates	-1.17** (.15)		.249** (.010)
Female Doctorates	2.76** (.30)	-4.34** (.29)	.213** (.011)
Male Doctorates with sample constrained to:			
1988-1998	1.23** (.44)	-2.19** (.47)	.075** (.018)
1978-1987	.88** (.45)	-3.01** (.54)	.050** (.016)
Math/Science	-.67 (.42)	-1.18 (.63)	.192** (.014)
Math/Science	-1.32** (.22)		.189** (.014)
Other Fields	3.11** (.37)	-4.49** (.36)	.169** (.017)

^aAll models include dummy variables for fields and a cubic function of calendar year. Standard errors are in parentheses.

^bEither # of male or female bachelors degrees, consistent with the dependent variable.

**p<.01

Figure1: Number of doctorates granted in the U.S., 1971-1998

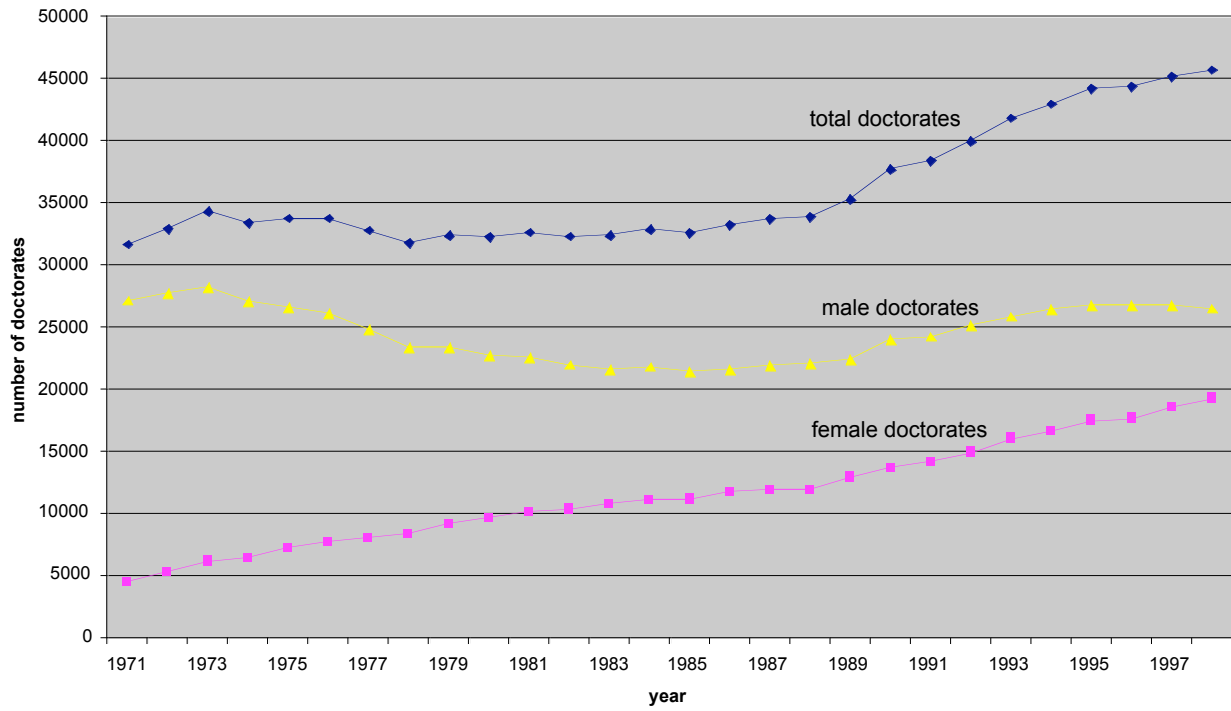
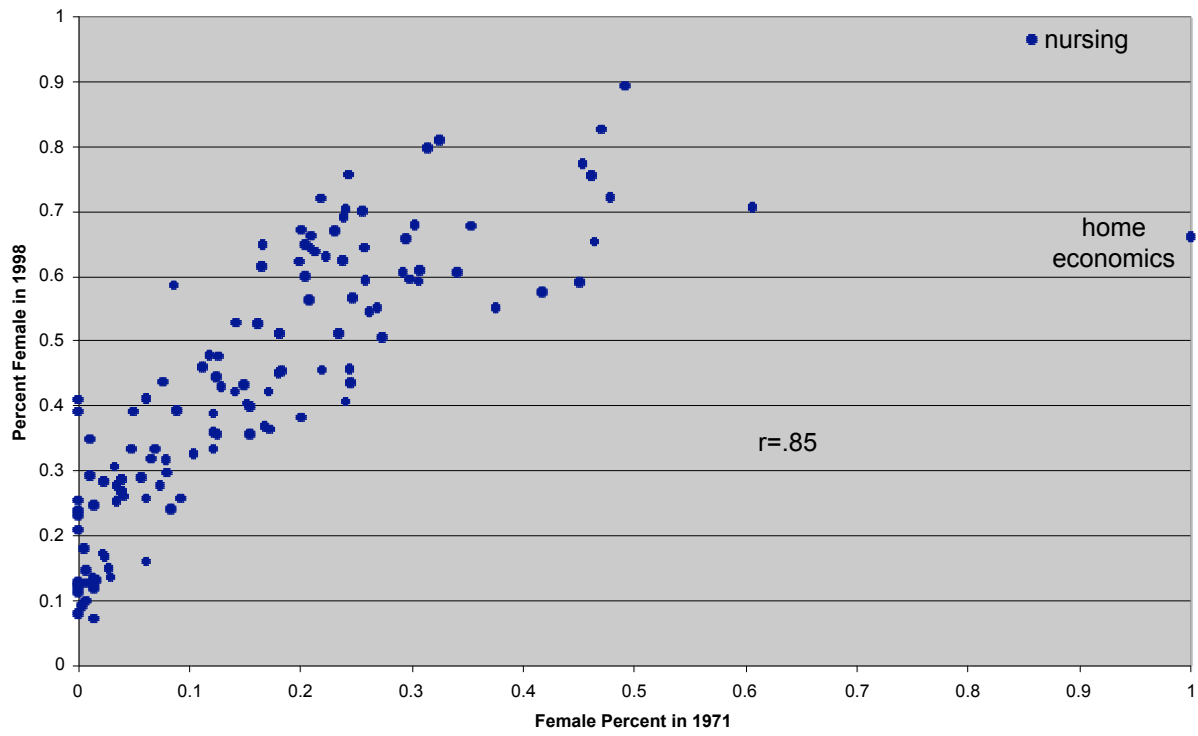


Figure 2: Correlation Between Percent Female of Doctorates Granted in 1971 and 1998



Note: Fields with <1000 doctorates from 1971 to 1998 excluded.

**Figure 3: Trends in percent female in selected large fields
(above the overall percent female line)**

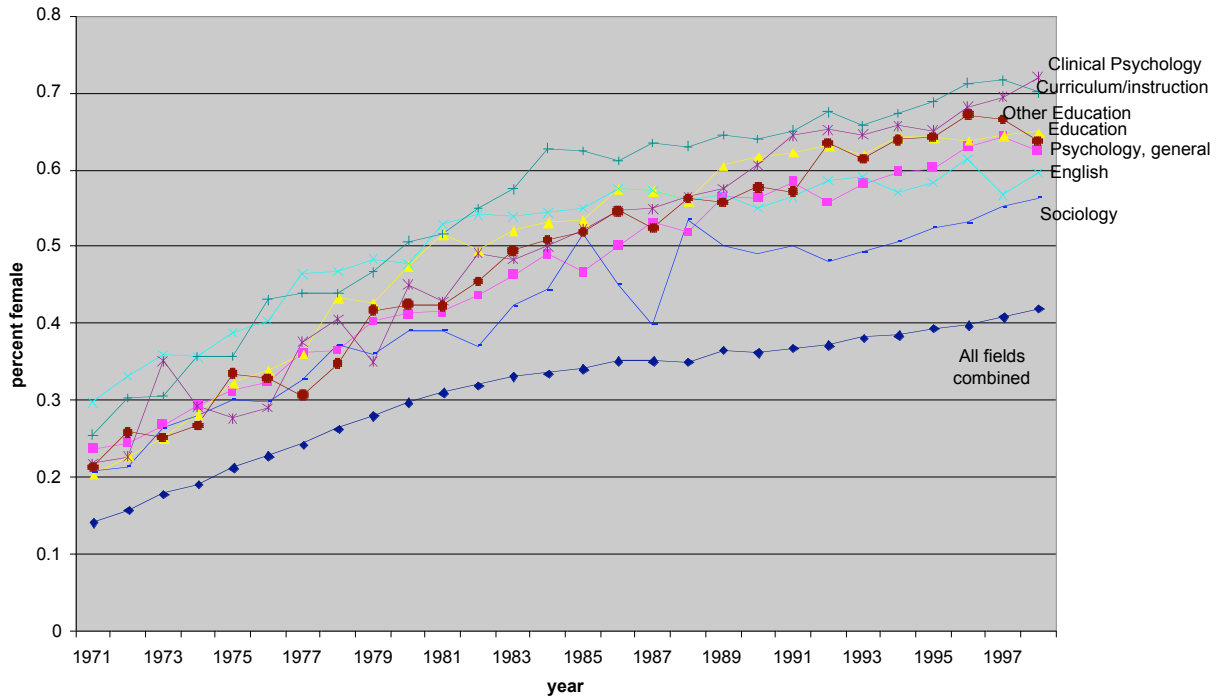


Figure 4: Trends in percent female in selected large fields (below the overall percent female line)

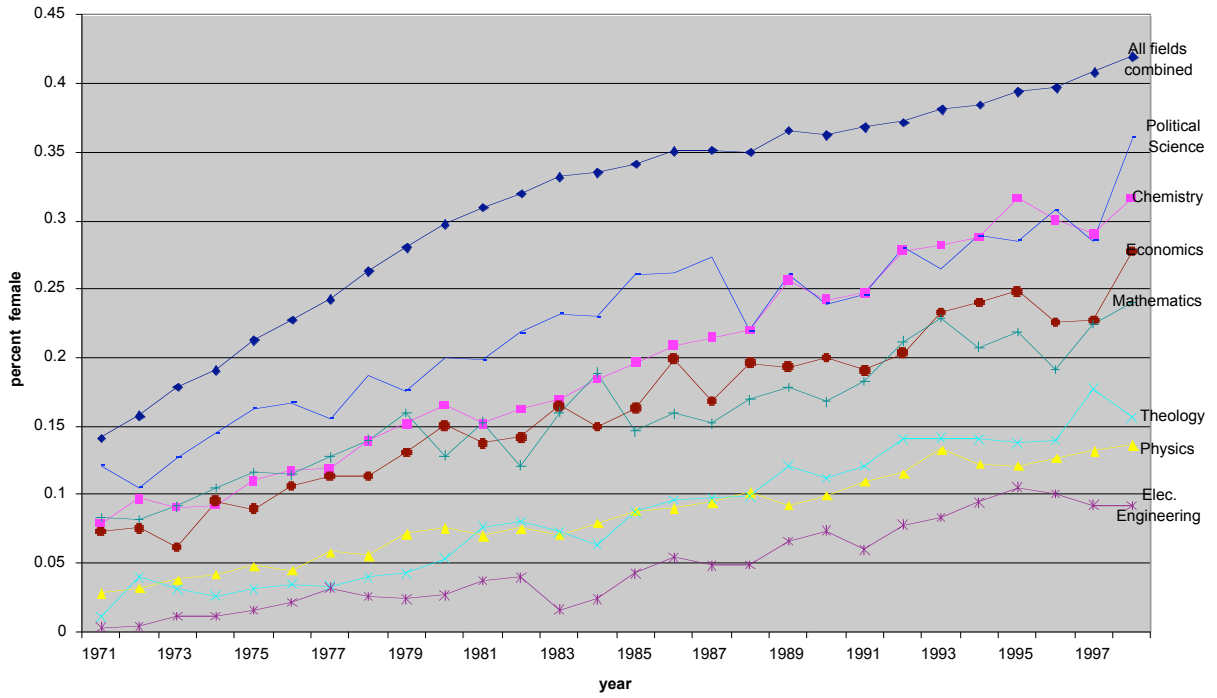
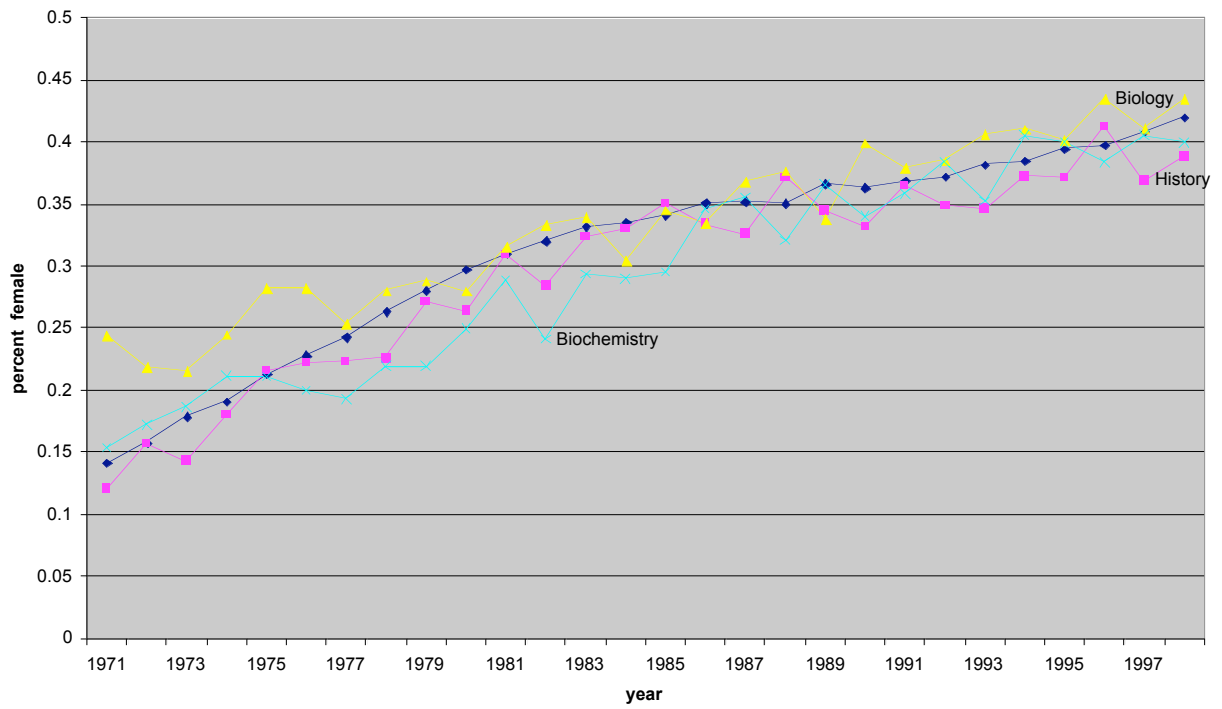


Figure 5: Trends in percent female in selected large fields
(near the overall percent female line)



**Figure 6: Trends in percent female in selected large fields
(cross the overall percent female line)**

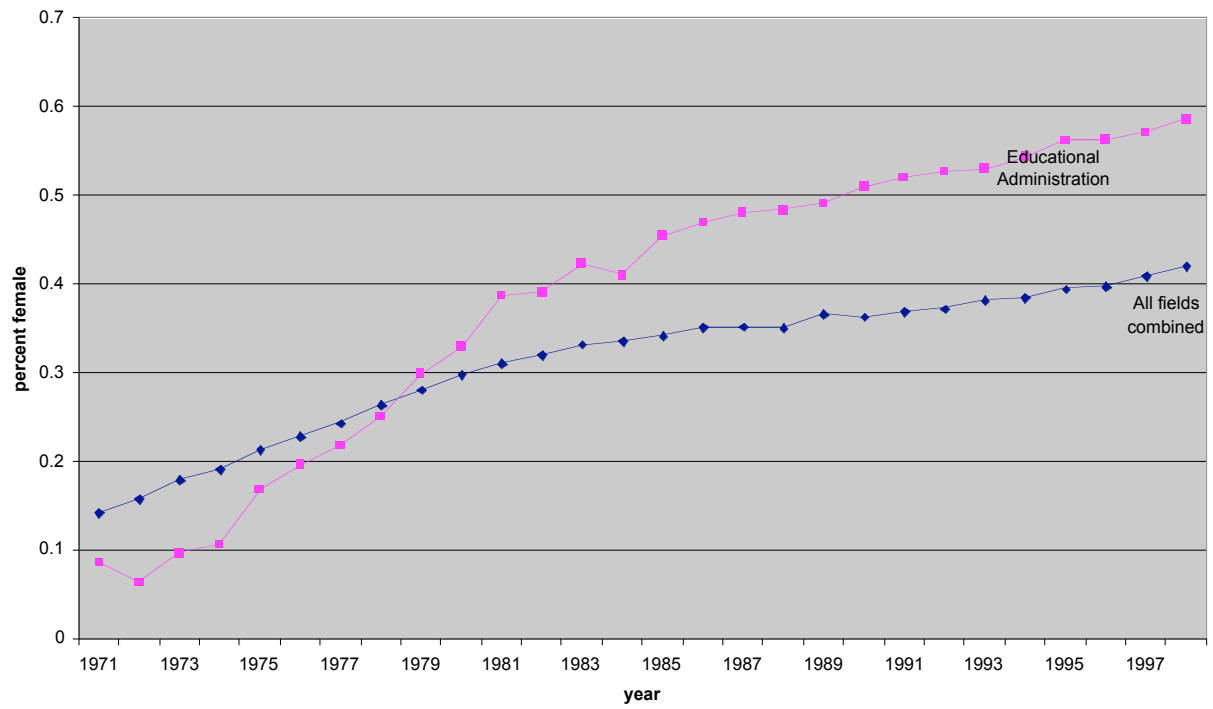


Figure 7: Quadratic Effect of Lagged Percent Female on Male Doctorates and Female Doctorates

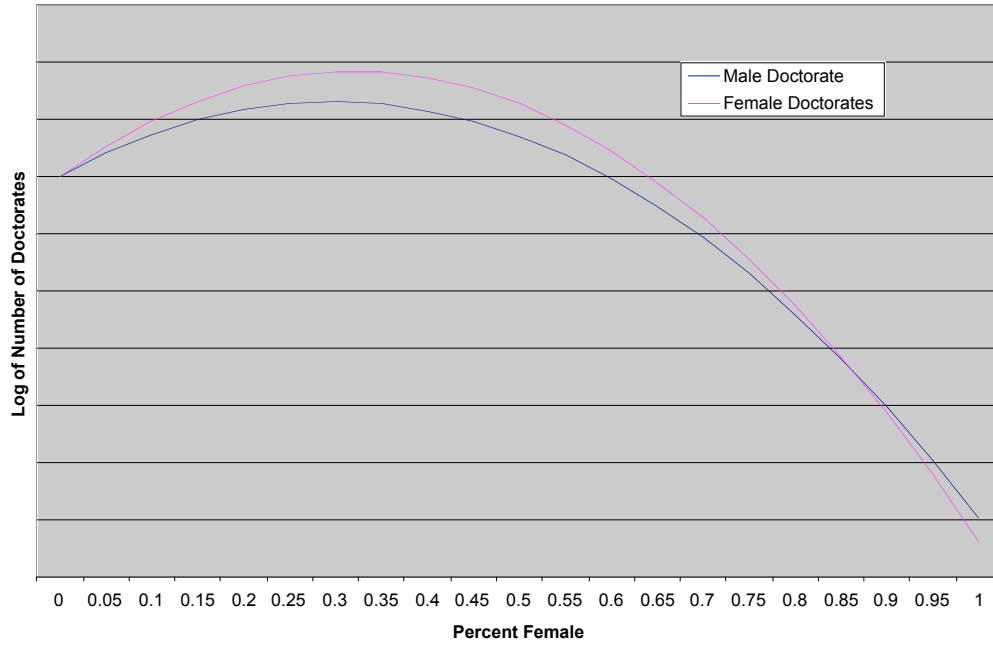


Figure 8

Quadratic Effect of Prop. Female on Male Doctorates By Period

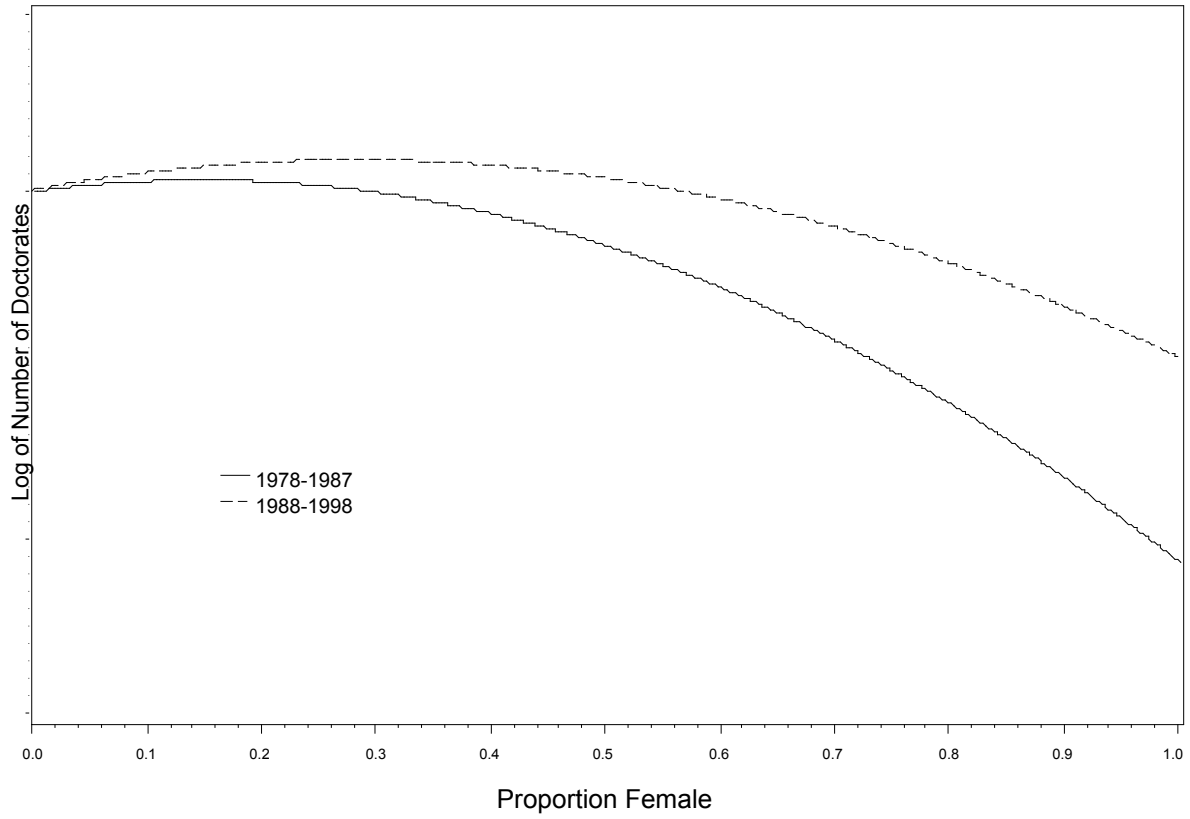


Figure 9

Quadratic Effect of Prop. Female on Male Doctorates By Discipline

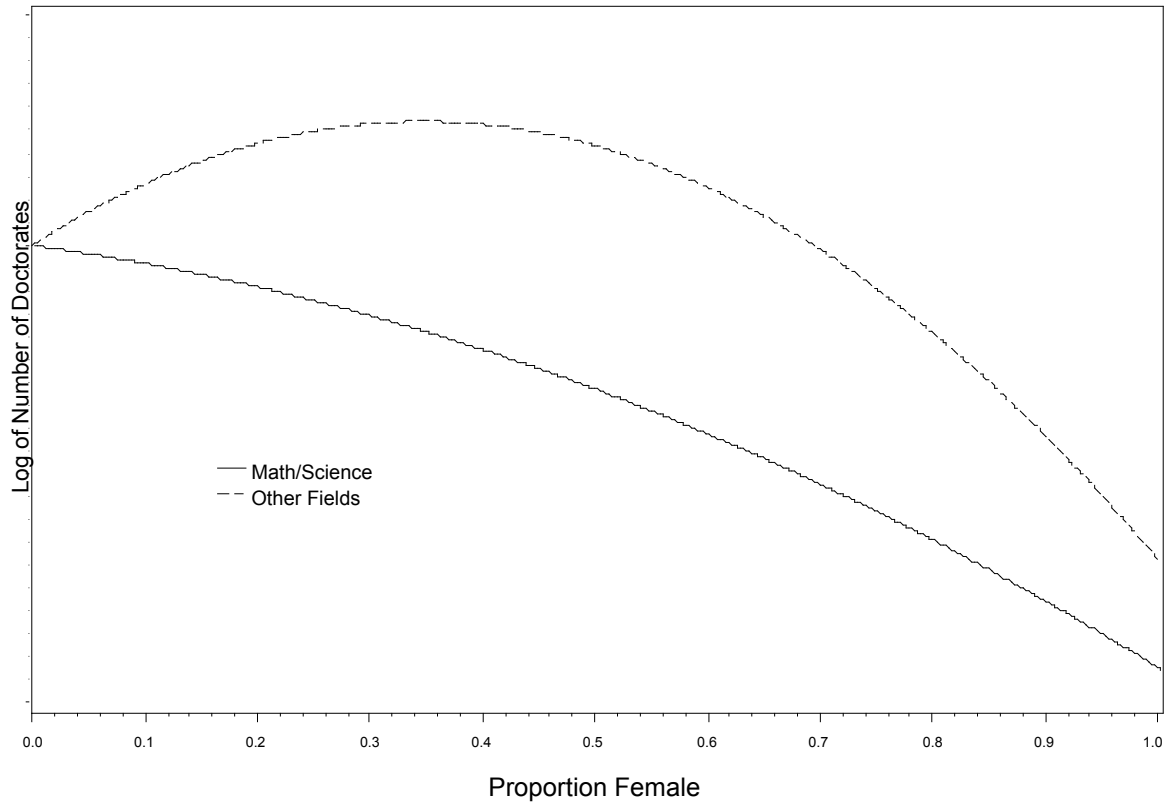


Figure 10

**Average Proportion Female Experienced by Males, Females and All Doctorates
Based on 1971 Proportions**

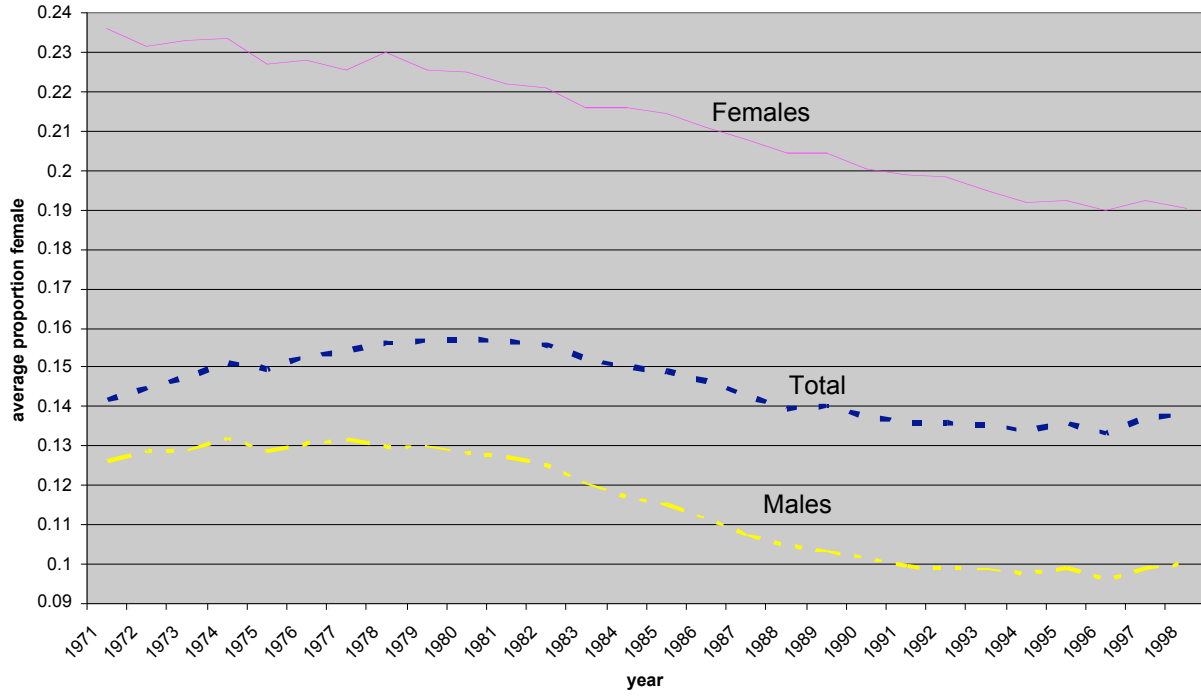


Figure 11

Quadratic Effect of Lagged Prop. Female on Male Doctorates,
Controlling for Contemporaneous Effect

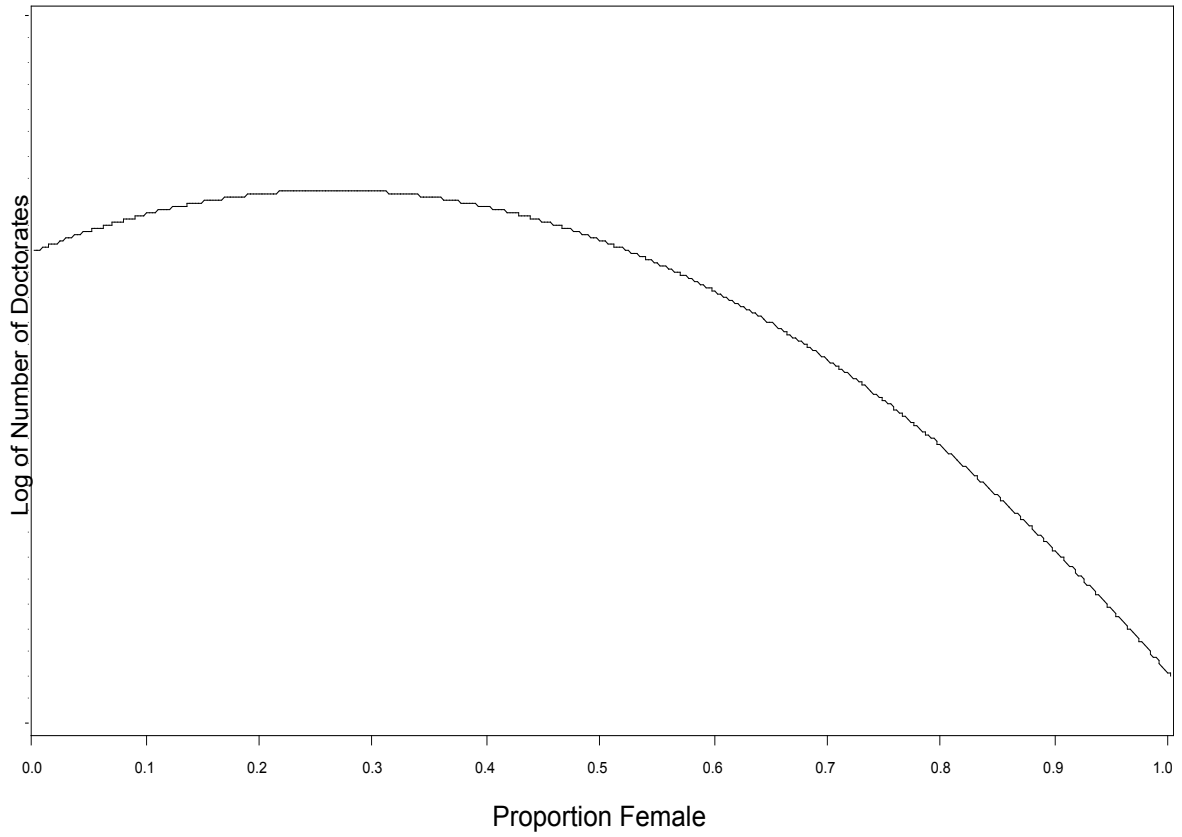


Figure 12. D,SSD and A of doctorates 1971-1998

