Degrees of Difference:

Gender Segregation of Doctorates by Field and Institutional Prestige in the US*

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Abstract

This paper reorients the literature on gender in higher education away from its current obsession with field of study (the "women in STEM" question) and toward a more nuanced understanding of gender segregation. It argues that men and women are segregated by the status of the institutions from which they receive doctoral degrees as well as by field. Institutional segregation may occur because men and women apply to, and matriculate at, different kinds of schools or because institution's admissions decisions differ according to their prestige. Using IPEDS data on doctorates awarded by field, institution, and gender, it shows that segregation across institutions and institutional prestige groups is substantial. The paper applies a series of log-linear and log-multiplicative models to identify patterns of segregation by institutional prestige, and evaluates these patterns against predictions drawn from the social psychological literature on status-based gender bias and the economic sociology literature on organizational status.

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Forty years ago, feminist scholarship began documenting the emergence of a new breed of academic: the woman. Among the early publications in the genre was Helen Astin's *The Woman Doctorate in America* (1969), a monograph whose title was unintentionally appropriate in its use of the singular: in the late 1950s, the cohort of PhDs from which Astin drew her sample, fewer than 10% of PhDs were women. Much has changed in the last half century. Women now constitute a majority of new BA recipients, the population "at risk" for graduate training, in the United States. And, although women who receive BA degrees are still less likely to go to graduate school than men, women now earn 46.1% of doctoral degrees (National Science Foundation, 2010).

The near parity in the proportion of doctoral degrees awarded to women masks considerable segregation by field of study (see, e.g., Ransom 1990; England et al 2007; Charles and Bradley 2002, 2009). The relative dearth of women in the physical sciences and engineering, in particular, has generated substantial attention in the academic literature on gender inequality (e.g., Xie and Shaumann 2003; Ceci and Williams 2010), higher education policy, and federal investments in efforts to expand the scientific workforce. Far less attention has been devoted to the overrepresentation of women in some academic fields, although a handful of studies have addressed the sources and consequences of such "feminization" (England et al 2007; see also Roos 1997; DiFuccia et al 2007).

In this paper, we seek to move the literature on gender segregation in higher education beyond its current obsession with disciplinary fields and toward a multi-dimensional understanding of segregation. More specifically, we lay out the case for studying gender segregation across the institutions that grant doctoral degrees (hereafter "institutional segregation" or "segregation by institution") as a conceptually and empirically distinct dimension of gender inequality than gender segregation by field. Our approach thus differs from one in which institutional segregation is treated as an artifact of institution-specific differences in the relative size of doctoral programs coupled with gender segregation by field (e.g., Gilford and Snyder 1977). That is, we argue that even after purging

out segregation by field and institutional differences in field coverage, men and women are unequally distributed across doctorate- granting institutions.[1]

Our interest in bringing institutional segregation to the study of gender inequality in higher education stems from our belief that the literature on gender segregation in higher education has much to learn from the literature on gender segregation in labor markets, which long ago recognized the importance of organizational context (see, e.g., Bielby and Baron 1984, 1986; Reskin 1993). However, whereas much of the labor market literature focuses on objective features of organizations (e.g., size, market position, bureaucratization, and founding conditions) that ostensibly affect men and women's segregation into different occupations or jobs, we focus on the subjective ranking of the doctorate-granting institutions. [2] An institution's position in the larger status order of colleges and universities affects the gender distribution of the doctoral students receiving degrees from that institution.

In making our case for the importance of an institutional approach to understanding gender inequalities in higher education, we draw heavily on two prominent literatures about status. The social psychological literature on how gender status beliefs affect assessments, and self-assessments, of competence (e.g., Ridgeway 1997; Correll 2001, 2004) inform our predictions about how institutional context affects students' application and matriculation decisions. The burgeoning literature on organizational status orders (e.g. Podolny 2007) and, in particular, Phillips and Zuckerman's (2001) elaboration of the old idea of middle-status conformity, informs our predictions about how institutional actors' admissions decisions, which in turn affect the gender composition of

[1] As is implicit in the above discussion, we focus exclusively on segregation among doctoral degree recipients. Although the fraction of doctorates in the population remains quite small, the doctoral degree is increasingly, and often explicitly, a requirement for most positions in academe and many research positions in industry. We exclude professional degrees (e.g., the MD, JD) because we assume that the factors that lead students to select particular professional programs, and professional programs to select particular students, differ from those that govern selection into doctoral training programs.

[2] We focus on institutional rankings, not departmental rankings. This decision is partly pragmatic: each institution can be assigned to one and only institutional ranking, allowing us to generate a three-way table of institution by field by gender (see Methods, below). However, it also reflects the literature on academic careers, which shows that the rank of the institution has an independent effect, above and beyond the rank of the department from which the degree was awarded. In extensions of this paper, we intend to explore gender segregation by the department and institutional prestige, which will require a field-specific approach.

incoming cohorts, are shaped by the institutions' location in the status order of colleges and universities.

Why does it matter? In our view, gender segregation in higher education is an object of inquiry in its own right: it is an observable indicator of the extent to which a society lives up to egalitarian ideals that are, if anything, especially strong in the education sector. Segregation is also of interest, however, because of its consequences for gender inequalities in the labor market. And, just as gender segregation by field is a precursor of segregation by occupation, gender segregation by institutional prestige perpetuates inequalities in men and women's post-graduate school labor market experiences within a field.

It is by now well known that the prestige of the degree-granting institution is strongly correlated with career outcomes in academia, including the likelihood of obtaining a tenure-track position, the ranking of the department in which the first-tenure track position is secured (Baldi 1994; Burris 2004), and the likelihood of earning tenure (Reskin 1979; Long and Fox 1995). We remain agnostic in the debate over whether these correlations stem from selection (higher-status programs admit stronger students), training (higher-status programs have better faculty, who train students more effectively), networks (higher-status faculty have more friends in high places), signaling (departments accrue prestige by hiring PhDs from high-status universities), or some combination thereof. For our purposes, it suffices that if women in a given field are more likely to receive their doctoral degrees from lower-status institutions than men, they will similarly be disadvantaged in career outcomes that are affected by the prestige of the degree-granting institution. Although intra-prestige group "inbreeding" occurs at all levels of the status hierarchy, it is especially consequential for the low prospects for upward mobility into the elite institutions (Baldi 1994; Burris 2004). In our view, the literature on women in the academe, and in particular in academic science, has not sufficiently appreciated that women's underrepresentation among faculty positions in the top echelons may be rooted in their underrepresentation in high-prestige doctorate-granting institutions.[3]

[3] As far as we can tell, Jacobs (1999) is one of the few gender scholars to tackle segregation by institutional ranking. However, he was primarily interested in undergraduate degree completion, as opposed to our focus on the doctoral level. We think the processes that generate the gender composition of undergraduate institutions differ in important ways from the processes that generate selection into graduate school programs. For example, undergraduates typically choose an institution before they choose a (final) major, this decision may be more affected by tuition concerns, and face much more ambiguous information about the relationship between prestige of the BA institution and future earnings. Moreover, Jacobs' methods did not allow him to neatly disentangle field segregation from institutional segregation.

Finally, we believe that a study of gender segregation by institutional prestige (net of field) is overdue where the goal is devise effective higher education policies to increase the diversity of the faculty. Many colleges and universities have adopted pipeline-based hiring goals, which specify that the gender composition of junior faculty hires should mimic, more or less, the gender composition of "the pipeline" in a particular discipline or field, lagged in some disciplines to account for post-doctoral training.[4] In establishing these goals, several commentators have argued – or at least assumed – that the gender composition of PhD pipelines differs across institution type, and they tie pipeline goals explicitly to the PhD production of peer or more highly ranked institutions. Nancy Hopkins, one of the lead authors of the MIT report that sparked the latest push to increase women's representation in academic science, writes, "to fully understand the pipeline… one would need to know the percent of women receiving PhDs in science over time *from the types of universities* whose graduates we hire" (2006, italics added). Curiously, the implicit assumption – that pipelines from higher status doctoral institutions are less diverse than pipelines at lower-status institutions – is entirely untested. We think a test of this assumption is critical: institutional efforts to increase the diversity of the faculty are doomed to failure if the goals are set in such a way that the real hiring agents, namely faculty, believe that meeting them will require hiring from lower-ranked institutions.

Our goal, then, is to offer a systematic assessment of gender segregation in higher education by institution *and* field of study, treating each as independent dimensions along which men and women are differentially arrayed. We spend little space on the factors that push or pull women and men into particular fields (e.g., economics), which have been discussed extensively in the existing literature on gender segregation in higher education in general and women in science in particular (see, e.g., Xie and Shaumann 2003). Instead, we focus on sources of (net) institutional segregation and institution-specific levels and patterns of field segregation. To what extent is the total association between gender and institutional status driven by segregation by field? Does the pattern of institutional segregation follow a gradient, such that higher prestige institutions are more segregated than lower-prestige institutions, assuming equivalent levels of field-based segregation? Or do levels and patterns of field-based segregation differ across institution types, and if so in what ways? In so doing, we

[4] To be sure, some institutions may hire above the pipeline in a given field, and others below. However, assuming that institutions require PhDs and also that most junior hires in US institutions received their PhDs in the US, in the aggregate the gender composition of the PhD pipeline constitutes the upper bound of the gender distribution of junior faculty hires.

hope to forge a new connection between the burgeoning literature on organizational status hierarchies (see, e.g., Podolny 2007) and gender inequality scholarship.

The remainder of the paper proceeds as follows. First, we elaborate the link between institutional status and gender segregation, drawing on two prominent theories of status – status characteristics and middle-status conformity – to generate testable, and contrasting, predictions about the pattern of institutional segregation and of field-based segregation by institution type. We then turn to a discussion of the data we will use for the project and the models that will allow us to tease out segregation by institutional prestige from segregation by field. We conclude with preliminary results and a list of the tables and figures that we will generate over the next two months, in advance of the PAA deadline for submitting complete papers.

Sources of Institutional Segregation

The gender composition of the PhD pipeline from a given program (e.g., Economics at Brown) is a function of two variables, neither of which can be directly observed in data on doctoral degree recipients: (1) the gender composition of the program's incoming cohorts, and (2) gender-specific attrition rates from the program.

In considering the first process, it is useful to begin with a basic model of how students are matched to doctoral programs, irrespective of gender. (We assume that the decision to enter graduate school, and to enter in a specific field, is made independently of and prior to the decision to attend a particular institution, and we treat it as exogenous to the student-program matching process.[5]) This match is the result of three sets of decisions: students choose where they will apply, institutions choose the students to whom they will extend admissions offers, and students choose where they will matriculate from among the subset of schools that have extended them offers.

At each stage, the relevant actor tries to maximize returns (pecuniary or nonpecuniary) relative to alternatives. So, for example, students apply to the subset of programs where they have a nonzero chance of matriculation, recognizing that applications are not cost-free, and where they have a non-

[5] We recognize that this assumption does not obtain universally. For example, students may apply to more than one field (e.g., sociology and economics, sociology and organizational behavior) and choose the program (and hence field) based on an evaluation of the offers. Or, they may decide not to enter graduate school after receiving offers of admission, especially if the offers of funding fall short. We see no reason to assume, though, that this "noise" will affect estimates of gender segregation by field or institution.

zero chance of acceptance, recognizing that they are in competition with other applicants (see also Attiyeh and Attiyeh 1997). Institutions select doctoral students from among their applicant pool who will maximize returns on the opportunity costs of making offers, recognizing that they are in competition with other programs for "the best" students, and on the time and money invested in training the students. The "returns" to the institution include the research and teaching performed by graduate students as well as the prestige accrued to the program when a graduate student goes on to a high-status position in academia (Breneman 1976; see also Burris 2004). And, students matriculate at the program (from their set of admissions offers) that will provide the best combination of training, opportunities for intellectual growth, prestige, future job prospects, and intellectual match at the lowest monetary and psychic cost.

Our goal is not to provide a comprehensive model of all three sets of decisions. Rather, we focus on how the prestige of the doctoral institution affects each decision in gender-specific ways, generating incoming cohorts that differ in their gender compositions. Male and female applicants differ in their likelihood of applying to high-prestige, middle-prestige, and low-prestige institutions. Institutions make different admissions decisions according to their position in the status order, and in so doing generate cohorts of differing gender compositions. And male and female students may give different weight to the status of the institution, relative to other considerations, when deciding which offer of admission to accept.

Students' Application and Matriculation Decisions

Why might men and women choose to apply to, and matriculate at, institutions that differ in their prestige levels?

Assume that men and women choose application schools based on the perceived match between their abilities, the schools' requirements, and their expected competitiveness with other applicants. Also assume that applicants use an institutions' ranking as a proxy for the average ability of its students. If the average male prospective graduate student in a given field (e.g., math) has stronger qualifications, for example higher test scores or grades in a subject than the average female prospective graduate student, men will be overrepresented in the applicant pool of top-ranked institutions, and women will be overrepresented in the applicant pool among lower-ranked institutions, because of self-selection based on perceived chances of admissions. Conversely, women

will be overrepresented in the applicant pool to high-status institutions in fields where women are the stronger applicants.

The existence of gender-based ability differences is, of course, highly contentious, especially in the literature on women's representation in math and the physical sciences. The psychometric literature finds that men and women are not equally represented among the students in the top 5% of the distributions on standardized tests of math, science, verbal reasoning, or writing ability (Wai et al 2010). Estimates of the current male:female ratio among the group of very top scorers (i.e., top 0.01%) differ somewhat by data source, but suggest a 2:1 advantage for men in math and scientific reasoning and a roughly comparable 2:1 female advantage in verbal reasoning and writing ability (Wai et al, 2010). These estimates are based on data collected on high school students (e.g., through the SAT or ACT), but it seems reasonable to assume that the right-tails of the ability distributions among students applying to graduate school show similar patterns, if not levels, of gender representation. If we furthermore assume that applicants to graduate school are drawn from the right-tails of these distributions, not from the median, self-selection based on ability would be sufficient to generate a (a) monotonic positive relationship between the rank of the institution and the degree of male overrepresentation in fields in which more men than women are found in the right tail of the ability distribution, and a monotonic negative relationship between the rank of the institution and the degree of male overrepresentation in fields in which more women than men are found in the right tail of the ability distribution.

"Pure" ability, whether learned or innate, may of course not be the only source of gender-based self-selection into high- or low-prestige institutions. A now voluminous body of experimental (e.g., Ridgeway 1997; Wagner and Berger 1997) and survey-based research (e.g., Williams and Best 1990; Fiske et al 2002) shows that men and women tend to believe that men are more competent and capable than women. The effect is general, in that men are generally thought to be more competent than women, but also especially strong where the task is associated with the stereotypical traits and abilities of men (e.g., math reasoning, spatial ability). These gender-based expectations of competence (or "gender status beliefs") inform external evaluators' assessments of competence and capabilities, and also inform the criteria that external evaluators use to just competence: men often have their performances judged by a more lenient standard than women (e.g., Foschi 2008).

Importantly, however, the same processes affect the assessments that individuals make of their own competence at career-relevant tasks. In particular, women evaluate their own competence and abilities more negatively, and apply stricter standards, regardless of their actual ability (e.g., Correll 2001, 2004; Foschi 1996, 2008). These assessments may be reinforced by significant others in the applicants social network, including family members, friends, or advisors. As a result, women may not apply to as highly ranked institutions as men with the same level of prior achievement and demonstrated ability, and they will be underrepresented in high-status institutions and overrepresented in low-status institutions. This effect will presumably be strongest in math, science, and engineering, the fields that are stereotypically male. However, it should be observable in all fields, given beliefs about men's general competence in all tasks requiring higher cognitive functioning.

Much of the prior discussion centers on prospective graduate students' decisions about where to apply. How about their decision to matriculate? This decision, too, could be affected by unconscious biases and self-assessments: women may be more likely to choose a lower-ranked institution even if they are admitted to higher-ranked institutions. Other research suggests that women and men choose graduate programs based on different criteria: specifically, women are more likely than men to choose a graduate program based on its proximity to home (e.g., Blau and Ferber 1983; see also Jacobs 1999 for a similar finding at the undergraduate level), presumably because they are more likely to have a spouse or partner who is comfortably employed. All else being equal, this would tend to distribute women more equally across the institutional prestige structure than men, leading to male overrepresentation in higher-prestige institutions across all fields. We suspect, that the gender gap in preferences for geographic proximity have weakened substantially since Blau and Ferber's study, which used data collected in 1979 on cohorts enrolled from 1968-1975. First, more men are married to employed women, thereby making the factors they must consider in choosing a graduate school more in line with women's; and second, the academic job market itself has gotten tighter, making it riskier for prospective students to indulge in geographic preferences over other factors (e.g., quality measures, prestige measures, funding availability). The tightening of academic labor markets likely had a greater effect on women who as a group valued geographic proximity more to begin with. We thus anticipate the geographic proximity effect to be quite weak, but note that it generates a similar prediction as the unconscious bias literature, and if we find this pattern we cannot disentangle its two potential sources.

Institutions' Admissions Decisions

Institutional actors may, of course, hold the same unconscious biases about women's competence as the rest of the population. Certainly the conditions under which admissions decisions are made are tailor-made for unconscious biases to affect outcomes. Decisions are often rushed, both because of constraints on faculty time and because of the perceived need to get offers out with the competition. Moreover, admissions decisions are based on information that either does not lend itself to objective comparisons using consistent criteria (e.g., letters of recommendation and statements of interest) or has notoriously little power to predict completion and future career success (GRE and undergraduate GPA; see, e.g., Zwick 1991). In conditions of high uncertainty and incomplete information, unconscious biases as especially likely to inform assessments of competence (Wagner and Berger 1997). These biases should favor male applicants over equally qualified women (see, e.g., Steinpreis et al). This is not to suggest that *no* women will be admitted, of course; indeed, if women judge their own abilities by a stricter standard then men do, gender-based self-selection may mean that women applicants to an institution at a given prestige level will be *more* qualified, on average, than male applicants.

The key question, of course, is whether there are institutional differences in the extent to which unconscious biases operate. The social psychological literature assumes that beliefs about men's superior competence, especially on stereotypically male tasks, are widely shared within and across cultural contexts. If all graduate admissions committees in a field are equally affected by the same biases, one would not anticipate biases at the point of admissions to lead to segregation by institutional status, above and beyond that generated by supply-side processes. In theory, institutions may differ in their accountability, the degree of consensus about relevant criteria for assessing candidates, and transparency in the decision-making process, thereby leading to institutional differences in the extent to which gender affects assessments. But, we see no obvious reason to assume that these conditions vary systematically with institutional prestige.

We argue that institutions do, in fact, make different admissions decisions based on their position in the status order, but these decisions have little to do with unconscious biases that advantage or disadvantage *applicants* of a given social status (e.g. women). Rather, an *institution's* status affects the extent to which it can "innovate" in its decisions, including its admissions decisions. In particular, institutions that risk moving down in the status order, or across socially salient boundaries, are more

conservative in their admissions decisions than high- or low-status institutions. This is, of course, the concept of middle-class conformity, an old idea that has recently been revived in the literature on organizational status (see Phillips and Zuckerman 2001).

The theory of middle-status conformity assumes, first, that actors value status. Actors will make decisions that minimize the risk of moving down in the status order and maximize the probability of moving up in the status order. Actors' initial positions in the status order affects the risk associated with a nonconforming behavior. High-status and low-status actors are free to buck convention ("innovate"), because their actions will have little effect on their status position. Of the two groups, high-status actors buy into the system and will be relatively conservative; low-status actors, by contrast, are outsiders to the system and least conforming (Phillips and Zuckerman 2001, p. 386). Middle-status actors will be more conforming than both groups because of their greater insecurity in the status order: they risk falling out of a preferred status group. Presumably, actors near the boundaries of socially significant status groups (e.g., top 10, top 20, top 100) will also be more conforming.

Do universities meet the scope conditions for middle status conformity to emerge (see Phillips and Zuckerman 2001, p. 388)? At a minimum, the actors must value status. Given the breathless anticipation with which faculty (and administrators, silently) greet the release of new institution rankings, we think this condition is met unambiguously. Moreover, there must be sufficient stability in the status order to create security for high-status actors, but sufficient instability in the status order for middle-status actors to feel insecure. Here, too, we believe that university prestige rankings meet these conditions. Institutional prestige rankings are notoriously sticky, and long-distance moves in particular are exceedingly rare. Given the similar macroeconomic environments under which university's upward mobility projects take place (e.g., expanding the faculty, raiding stars), the odds that a high status institution will be dislodged from the top, or that a low-status institution jump to the middle of the status order, are relatively low. The long odds that low-status institutions, in particular, face may make them less likely to buy into the status ranking system at all, and more likely to either challenge its legitimacy or simply ignore it than middle-status institutions and high-status institutions, for all their administrators may feign disinterest in the rankings.

Critically, however, institutions do move up and down in these rankings, if not by leaps and bounds than by a slow creep. Such mobility is especially likely in the middle of the status order, where large

numbers of institutions are differentiated from one another on the basis of relatively little information. The gold-standard NRC rankings, for example, are based on external observers' Likert-type assessments of a mere 41 program areas, generating estimates that are "noisy." However, even if mobility in the status order is based on noise, it is still consequential for institutions' ability to secure students and external resources.

The final piece of the puzzle is the decision itself. Phillips and Zuckerman (2001) argue that the types of decisions that are affected by organizational status are those pertaining to innovation in market decisions (e.g., a law firm's decision to enter family law). Are decisions about the gender composition of cohorts subject to the same status processes? We think that although institutions' admissions decisions are not directly evaluated by their audience, their long-term records with respect to gender are, both by external audiences (e.g., peers within the discipline) and internal audiences (e.g., faculty, administrators). No institution wants to earn a reputation of being unfriendly to women (or men). At the same time, the gender distribution of graduate cohorts is not under such scrutiny that a highly unusual distribution would delegitimate a high-status actor. A high-status institution that admits all-male cohorts of students in their physical science doctoral programs is not at risk of a status hit; in this case, this behavior runs contrary to egalitarian norms and prevailing institutional pressures toward gender diversity of the faculty, but does not carry a severe threat of delegitimation.

The "action", in this case, is the joint set of admissions decisions that generate the gender distribution of incoming cohorts. It bears emphasizing that an institution and its agents need not *intentionally* admit all-male cohorts. In fact, they may end up with such a cohort quite unintentionally, whether through gender-based ability distributions or through unconscious gender biases. We assume, however, that institutional agents are cognizant of the gender composition of the pool of candidates to whom they wish to extend offers. In the hypothetical case of an all-male physics cohort, the institutional agents decided *not* to diversify it. Intentional inaction, in this case, is a form of action.

One critical question remains, though: "conformity to what?" Are institutions that admit a more gender-diverse pool of candidates relative to prevailing standards in the discipline conforming or nonconforming? The answer, we think, is "both." Institutions that admit diverse cohorts are conforming to audience expectations for diversity, where the audience is comprised of institutional

administrators, peers at competitor institutions, and nonacademic evaluators. They are nonconforming, however, to widespread cultural beliefs that (a) positions in graduate programs should be based solely on ability, and (b) men are "naturally" better at advanced cognitive study, especially in science and related disciplines. The key empirical prediction of the theory, then, is not that the u-shaped curve is convex or concave, but merely that the relationship between institutional status and segregation is u-shaped. Put differently, levels of gender segregation in high-status and low-status institutions will be more similar to each other than they are to levels of segregation in middle-status institutions. Levels of field-based segregation will similarly be alike in high- and low-status institutions, and different in middle-status institutions.

Attrition

As we noted above, the gender composition of doctoral degrees awarded is only partly a function of the gender composition of incoming cohorts: attrition from the program also matters. Attrition will affect the observed level of institutional segregation, as we measure it here, if and only if doctoral candidates are more likely to drop out of a given institution type's doctoral program, net of any field-specific differences in attrition. Similarly, patterns of field-based segregation will differ across institution types if, and only if, within a given field any gender differences in attrition rates differ by institution type. If the only dimension on which we observe gender-specific attrition is across fields, and the pattern is such that the gender least represented in the incoming cohorts is most likely to drop out, we will observe greater field-based segregation in the degree completion tables than we would have in the incoming cohort tables but the observed levels of institutional segregation, and institution-field segregation, will be unaffected.[6]

[6] Consider a hypothetical world in which there are two fields, math and biology, and two institutions that offer degrees in math and biology, Institution A and Institution B. Assume, further, that both genders are equally represented in all four incoming cohorts (math in Institution A, biology in Institution A, math in Institution B, and biology in Institution B). If math students are more likely to drop out than biology students (see Baker 1997, Table 4), the marginal distribution of completed doctorates in math and biology will be affected relative to the underlying (and unobserved) tables cross-classifying matriculation by gender, field, and institution. If women math students are more likely to drop out than men math students, we will observe field-based segregation in the degree completion tables, but no institution-based segregation. Similarly, f Institution A has higher attrition than Institution B, perhaps because Institution A offers less funding, the institution margins will be affected, but we will not observe institutional segregation in the degree completion tables unless the attrition rates in each institution differ by gender. We will only observe both forms of segregation in the completion tables if the gender gap in attrition rates differs across fields and institutions independently.

Is attrition gender-specific? In the absence of a centralized source of data on incoming graduate cohorts, most of the data come from individual institution's longitudinal tracking efforts (e.g., Berg and Ferber 1983; Zwick 1991; Ehrenberg and Mavros 1995; Nerad and Miller 1996; Lott et al 2009) or nonrepresentative groups of graduate students (e.g., Baker 1997; but see Nettles and Millett 2006). Within-institution studies generally find that women have greater odds of attrition than men, but that much of this gap is due to men's overrepresentation in math and sciences (e.g., Lott et al 2009; Zwick 1991; Berg and Ferber 1983; Ehrenberg and Mavros 1995). In these disciplines, completion rates for both genders are higher and completion times shorter, making right-censoring of institutional data less problematic (Zwick 1991). Berg and Ferber (1983) further find that once one accounts for enrollment in doctoral programs where the MA degree is a status-conferring terminal degree (e.g, education), gender gaps in attrition largely, although not entirely, disappear. Moreover, the size of the gender gap varies by discipline, such that gender gaps *within* English, math, and the physical sciences are trivial (Baker 1997; see also Nerad and Miller 1996, Nettles and Millet 2006). They also appear to be narrowing over time; indeed, Baker (1997) argues that by 1980 and 1981, women who applied to NSF's graduate fellowship programs had higher completion rates in the life sciences than men. The conclusion we draw is that gender differences in attrition contribute to field-based segregation, but once one "controls for" field, the remaining gender differences in attrition rates are muted and discipline-specific, but still present.

Are the gender-differences in attrition within fields associated with institutions, and in particular institutional prestige? Data limitations have so far prevented other researchers from looking at institution-level differences in (net) gender gaps in attrition. We can, nevertheless, draw informed speculations. To the extent that women are more sensitive to funding constraints (Berg and Ferber 1983), we might anticipate that women will drop out of graduate programs at a higher rate than men in lower-prestige institutions, which typically cannot offer as generous graduate funding packages. Assuming equal representation of the genders at matriculation, this source of attrition would generate an overrepresentation of women in higher-status institutions relative to lower-status institutions. We have no a priori reason to believe, or evidence suggesting, that attrition rates across the two genders differ within a cell defined by *both* field and institution type, yielding institution-specific patterns of field segregation (or, alternatively, field-specific patterns of institutional segregation).

The preceding discussion offers ample reason to believe that men and women are segregated by institutional prestige as well as by field. Gender differences in representation in the very top of the ability distribution will generate more extreme gender segregation in high-status institutions, which are advantaged in the competition for budding geniuses in a field, than in lower-status institutions; moreover, patterns of institutional segregation will differ in predictable ways by field. Gender-based assessments of competence will generate more male overrepresentation in high-status institutions; this general pattern should obtain in all fields, but especially male-typed fields. Within a field, women's greater sensitivity to funding shortfalls may lead to their relative overrepresentation in higher-status institutions. And, on the demand side, middle-status conformity predicts a curvilinear relationship between segregation and institutional status, although whether it is convex or concave is an empirical question.

We think it striking that gender scholars have paid so little attention to the organizational context of segregation in higher education, and in particular to segregation by institutional status. We suspect that part of the reason for the dearth of empirical research lies in the complexity of teasing out segregation across two or more structures (e.g., fields, degree-granting institutions) simultaneously. We next introduce the log-multiplicative framework that allows researchers to secure these estimates.

Models

We first calculate summary measures that capture the extent of segregation by field (aggregating across institutions) and by institution type (aggregating across fields). We calculate two summary measures: the Duncan index (D) and the log-linear index (A). D is given by the following equation:

$$D = 50 \times \sum_{i=1}^{n} \left| (W_i / W) - (M_i / M) \right| \qquad (1)$$

where W_i refers to the number of women in the i^{th} field, M_i refers to the number of men in the i^{th} field, W refers to the number of women in all fields, and M refers to the number of men in all fields. It is interpreted as the percentage of women (or men) who would have to change fields in order for every field to graduate the same proportion of women doctorates as every other field. It can, of course, also be calculated for institutional segregation, substituting institutions for fields in the

equation above, and for institutional prestige segregation, substituting prestige categories for fields (see "data" section, below).

The closed-form solution for A is given by the following equation:

$$\ln(A) = \left\{ \frac{1}{n} \times \sum_{i=1}^{n} \left[\ln(W_i / M_i) - \left(\frac{1}{n} \times \sum_{i=1}^{n} \ln(W_i / M_i) \right) \right]^2 \right\}^{\frac{1}{2}} \qquad \textbf{(2)}$$

where n is the total number of fields (institutions, or institutional prestige categories), and all other symbols are defined as before. It measures the typical amount that the doctoral field sex ratios deviate from perfect integration, where perfect integration is defined by an identical (logged) sex ratio in each field. It is often interpreted as the multiplicative factor by which women (or men) are overrepresented in the average field (or institution).

In order to assess specific hypotheses about levels and patterns of gender segregation in both field of doctoral degree and institution, we need to shift from summary measures to a log-linear and log-multiplicative modeling framework. The benefits of these models for segregation research have been discussed extensively elsewhere (see, e.g., Charles and Grusky 1995, 2004; Grusky and Charles 1998). For our purposes, we merely note that the log-linear approach allows us to generate estimates of field segregation that are unaffected by institutional segregation, and vice versa. In particular, we adopt the elaborations to the now-standard log-linear and log-multiplicative framework that the first author and a colleague developed to examine job market segregation across industries and occupations simultaneously (see Weeden and Sorensen 2004).

We begin with a model of conditional independence (Model 1), which assumes that there is no gender segregation by field or by the prestige of the degree-granting institution. This model is unlikely to fit the data, but gives the total amount of association that needs to be explained. It is given by the following equation:

$$m_{ijk} = \alpha \beta_i \gamma_j \delta_k \lambda_{ik} \qquad (3)$$

where k indexes the prestige categories of the degree-granting institutions (see "data", above), i indexes field, j indexes gender, m_{ijk} is the frequency in cell (i,j,k), α is the grand mean, β_i is the marginal effect for the i^{th} field, γ_j is the marginal effect for the j^{th} sex, and δ_k is the marginal effect of the k^{th} institution category. The λ_{ik} allow the field distributions to vary freely by institution type.

The following "row effects" model (Model 2) assumes that there is constant field segregation across institutions of different prestige rankings, but no institutional gender segregation:

$$m_{ijk} = \alpha \beta_i \gamma_j \delta_k \lambda_{ik} e^{\phi(z_j \mu_i)} \quad (4)$$

In this model, the Z_j is an indicator variable of gender ($Z_1 = 0$ = men, and $Z_2 = 1$ = women). The scale values (μ_i) generated by this model define the pattern of segregation, i.e., they identify the fields in which women are over- or underrepresented. (We adopt the standard identification constraints for the μ_i by normalizing them to have zero mean and unit variance.) The ϕ parameter measures the strength of the field-by-gender association, with large values indicating more extreme levels of field-based gender segregation. The strength of segregation is assumed to be constant across institution types. In ignoring institutional segregation, this model is consistent with the majority of gender segregation research on higher education. However, it improves upon this research by offering an estimate of gender segregation that is purged of cross-field differences in the types of institutions in which degrees in those fields are granted.

The "layer effects" (Clogg 1982) model (Model 3) assumes that men and women are segregated across institution types, but not across fields:

$$m_{ijk} = \alpha \beta_i \gamma_j \delta_k \lambda_{ik} e^{\psi(z_j \nu_k)} \quad (5)$$

The interpretation of the parameters under this model is similar to that for Model 2. The scale values ν_k reflect the sex ratios of the different institution types (net of marginal effects), and the association parameter Ψ indicates the strength of sex segregation across institutions of differing prestige levels. Given the substantial research documenting field-based segregation, Model 3 is unlikely to fit the data, but nevertheless offers an estimate of institutional segregation net of cross-institutional differences in the representation of fields.

Model 4 combines the prior two models, thereby allowing for field segregation and institutional segregation:

$$m_{ijk} = \alpha \beta_i \gamma_j \delta_k \lambda_{ik} e^{\phi(z_j \mu_i)} e^{\psi(z_j \nu_k)} \quad (6)$$

This model (4) implies that women and men doctorates are segregated by both field and by institutional prestige. It assumes, however, that the pattern and strength of field segregation does not vary across institution types, and the pattern and strength of institutional segregation does not vary by field. The parameters are interpreted as before, although the μ_i now reflect field segregation *net* of institutional segregation, and the ν_k measure the institutional segregation net of field segregation. For example, a positive ν value for the category of "top 10" doctorate-granting institutions would indicate that men are overrepresented among doctorates of this institution even after we take into consideration the fact that the top 10 category includes MIT and Caltech, both of which have large engineering and small (or nonexistent) humanities programs.

Model 5 allows us to test whether variations in field segregation across institution types reflect differences in the level of field segregation, the pattern of field segregation, or both. It does so by assuming that in addition to institutional segregation, there is a generic pattern of field segregation common to all institutions: e.g., men are overrepresented in mechanical engineering in all institution types, and women are overrepresented in sociology in all institution types. The level of field segregation, however, is allowed to vary across institutions:

$$m_{ijk} = \alpha \beta_i \gamma_j \delta_k \lambda_{ik} e^{\phi_k(z_j \mu_i)} e^{\psi(z_j \nu_k)}. \quad (7)$$

Under this model, the ϕ_k track variations in the degree of sex segregation across institution types. Institution types with low values of ϕ_k have relatively compressed common scale values μ_i, meaning that the degree of field-based segregation is less extreme in these institution types. For example, women may be overrepresented in the field of sociology and men overrepresented in the field of mechanical engineering at all institution types, but the extent of this overrepresentation may be stronger in higher-prestige institution categories. As suggested earlier, such institutional variability in the strength of sex segregation may reflect differences in institutions' ability to recruit the strongest possible candidates in each field, status-based biases in evaluating prospective candidates' merits, or status conformity for middle-prestige institutions. By mapping the parameter estimates for each institution type, we will be able to assess whether there is a linear relationship between institution

type and the level of field segregation, as anticipated by the status-based evaluation and ability queuing models, or whether there is an inverted U-shaped relationship, as predicted by the middle-status conformity hypothesis.

If Model 5 fails to adequately characterize the data, the next step is a saturated model (Model 6):

$$m_{ijk} = \alpha \beta_i \gamma_j \delta_k \lambda_{ik} e^{\phi_k (z_j \mu_{ik})}. \quad (8)$$

Model 6 fits a unique scale value for each field-institution cell, thus allowing the pattern of field segregation to vary freely across institution types. It also fits a set of institution-specific phi values, which capture variations in the strength of field segregation across institution types. It is far from a parsimonious model. It will, however, allow us to address the assumption that university's pipeline-based hiring goals should be based on *peer* institutions' PhD pipelines.

Data

The data for this project are obtained from two sources. Data on graduate degrees by gender, field of study, and institution were downloaded from the National Center for Education Statistics' Integrated Postsecondary Education Data System (IPEDS). The IPEDS compiles and distributes data on degree recipients from American institutions. All institutions that participate in a federal financial assistance program are required by law to submit data to IPEDS, meaning that the data are comprehensive in their institutional coverage.

Each institution (n=778) is required to report the number, gender, and race of doctoral degree recipients in one of 789 Classification of Instructional Programs (CIP) codes. The CIP taxonomy was updated in 2000 and again in 2010, meaning that degrees obtained before 2000 (and after 2010) are not reported in a comparable scheme as degrees obtained in the 2000s. For the purposes of this paper, we aggregate all years of data that were reported in the 2000 CIP scheme, thereby allowing us to retain as much detail as possible in the CIP codes. We excluded the 2002 data, because an apparent coding error in the IPEDS database doubled the number of doctoral degrees reported in the 2002 data relative to that reported in either 2001 or 2003. Not including the 2002 data, 445,466 doctoral degrees were reported in the 2000-2009 IPEDS, corresponding to PhD cohorts graduating between 1999 and 2008.

The IPEDS data were used to generate a three-way cross-classified array of gender, CIP field, and institution. Even pooling the data across years, cell counts in some CIP codes were quite small. When the data are further disaggregated by institution type, small cell counts can generate instability in estimates of segregation (see, e.g., Weeden 1998, 2004). We thus aggregated the 789 six-digit CIP codes into 54, two-digit CIP codes. Although such aggregation can lead to an underestimate of the absolute level of segregation if the component categories differ in their gender distributions, it is less problematic (a) where the goal is to compare across institution types, and (b) where the subfields themselves are only partially institutionalized, as is the case where only a few of the reporting institutions offer this specific degree (e.g., a PhD in American History as a distinct degree from a PhD in History).

Data on institutional rankings were obtained from the National Research Council's 1993 data. (If the long-awaited update to the 1993 NRC rankings are released in late September , we will use it instead.) The NRC evaluated a total of 274 institutions that grant doctorates in at least one of 41 fields. It provides ratings of faculty quality and of the effectiveness of the program based on the assessments of other degree-granting universities in that field; as such, they are measures of reputation or prestige more than objective performance. The NRC did not compile these discipline-specific ratings into a single ranking of institutional prestige. We rely on Newton's (1997) ranking of 136 universities according to the average of their nonzero scores on the faculty quality measure in each of the 41 NRC fields. This ranking has considerable face validity, but supplementary analyses will explore whether alternative ranking schemes (e.g., average of all scores, USNWR rankings) generate substantively different results.[7]

We then aggregated institutions into prestige categories based on their NRC rankings. Although it would be possible to simply treat institution rank as an externally specified variate in a log-linear model, we think there is theoretical justification for grouping institutions of similar prestige. First, a substantial percentage of doctoral-granting institutions are not rated by the NRC. If we were to treat institution rank as a continuous variable, we would either need to exclude these institutions or assign them an arbitrary value on a prestige continuum. If we treat prestige as a categorical variable, by contrast, we can simply include a category for unranked institutions. Second, the middle-status

[7] Note to organizer: we intend to redo Newton's ranking when the new NRC data are released, and we will calculate a score for all NRC-ranked institutions, not just the top 136.

conformity hypothesis posits a U-shaped curve, not a simple linear function. Although it would be possible to embed this nonlinearity in the log-multiplicative scaled association framework (e.g., by fitting the quadratic or even cubic of institutional ranking as a separate dimension), this solution strikes us as needlessly complex. Most importantly, however, some status boundaries are more important to institutional actors than others: for example, the boundary between 8th and 9th place is not nearly as important as the boundary between 10th and 11th, because 10th allows the institution to claim "top ten" status whereas 11th does not. We accordingly create 17 categories of institutional prestige: top 10, 11-20, 21-30, …, 141-150, 151-162, and "unranked" in Newton's analysis of the NRC data.

Results (preliminary)

NOTE TO ORGANIZER. As of this writing, we have programmed, but not yet run, the log-multiplicative models. Because of their complexity, and the size of the prestige-group by field by gender array, they are extremely CPU intensive. We didn't think it made sense to run them so close to the release date of the new NRC rankings. We will easily be able to complete the remaining tasks before the deadline to submit the final paper.

The summary indices show substantial segregation by field and by institution (see Table 1). Looking first at field-based segregation, 36% of women (or men) would need to change 6-digit CIP field (n=789) in order to be equally represented among new doctorates in all fields; and women are underrepresented in the average field by a factor of 2.5. When we aggregate fields to the 2-digit CIP level (n=54), the indices decrease slightly to 0.33 (D) and 1.9 (A), but much segregation remains. These values are consistent with prior results reported for gender segregation by field in the United States (e.g., England et al 2007; Charles and Bradley 2009).

Segregation by institutions is likewise substantial. The dissimilarity index calculated for all 778 institutions in the data is 0.18, and the log-linear index is 2.7. Curiously, D implies less segregation by institution than by field, while A implies more segregation by institution than by field; we suspect this may be a function of A's greater sensitivity to small cell counts (e.g., Weeden 1998). When we aggregate the 789 institutions into 17 prestige categories and recalculate the segregation indices, we find that the value of D declines to .09, indicating that 9% of women would need to change institutional categories in order to be equally represented in all prestige levels, and the log-linear index decline to 1.2. The conclusions we draw are, first, that much of the segregation of men and women across institutions can be captured by prestige groupings; and second, although institutional

segregation is less extreme than field segregation, it is nonetheless a nontrivial form of gender inequality in higher education.

Here the manuscript draft ends. The list of additional tables to be included in the final paper is as follows:

Table 2: Goodness of fit statistics for log-multiplicative models of segregation in higher education

Figure 1: Under- and over-representation of women by CIP field, net of institution type

Figure 2: Under- and over-representation of women by institution type, net of CIP field

Figure 3 (or 3a-3c): Field scale values in selected prestige groups (from saturated model)

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Table 1: Summary Indices of Gender Segregation of Doctoral Degree Recipients by Field of Study, Institution, and Institutional Prestige Group

Unit of Segregation	**D**	**A**
Field of Study: 6-digit CIP code	0.36	2.50
Field of Study: 2-digit CIP code	0.33	1.95
Institutions	0.18	2.71
Institutional Prestige Groups	0.09	1.21

Note: Data are from the 2000-2008 IPEDS data. See text for explanation of variables.