SECTION 2. STUDY DESIGN

Phase I of this study examines whether the likelihood of successfully achieving outcomes at specific times along the academic career path is related to doctorate recipients' sex. Phase II is longitudinal and examines whether doctorate recipients' sex is related to the amount of time it takes to achieve career milestones. Both phases use data from nationally representative samples of people who earned doctorates in S&E and who are employed in academia. Both also use multivariate statistical methods that control for factors other than sex that might affect career success.

DATA

Data for both phases of this study were taken from the SDR. The SDR data include only those individuals who have earned S&E doctorates in the United States. Consequently, our analyses do not consider career outcomes of those employed in academia who have not earned doctorates, those who earned degrees in fields other than S&E, or those who earned doctorates outside the United States.

PHASE I DATA

The Phase I data include individuals who reported working full time in academia and who appeared in the 1981 through 1997 wave of the SDR. When this study was undertaken, SDR data were available for odd-numbered years 1973 through 1997; however, the surveys conducted during the 1970s do not provide sufficient detail on the ages and numbers of children (dependents), so we excluded them from our analyses. Some of our analyses required constraints on the samples we used. We describe these sample restrictions later in this section of the report.

PHASE II DATA

The Phase II data include doctorate recipients who reported full-time employment in academia in the 1997 SDR wave. Because this part of the analysis tracks individuals from the time they earned their doctorates until the time of the 1997 survey, Phase II also uses some data from earlier SDR waves. These data include information required to construct work and family histories.[1]

As in Phase I, some of the Phase II analyses required that we exclude certain respondents from the samples we used. These exclusions are described later in this section of the report.

PHASE I STUDY DESIGN

Below, we describe the Phase I models used to compare female scientists and engineers to their male counterparts. Specifically, we identify the career outcomes of interest, describe the statistical methods employed, list the control variables included in the analyses, and describe sample restrictions and model specifications.

CAREER OUTCOMES

Phase I focuses on three career outcomes for doctorate recipients employed in academia. The first, tenure track, is whether the individual is employed in a tenure-track position. The second, tenure, is whether the individual has earned tenure. And the third, academic rank, is whether the individual is employed at the rank of full professor, associate professor, or a junior rank (assistant professor or other rank below associate or full professor).

STATISTICAL MODELS

In Phase I, we used multivariate logit analysis as the primary statistical tool. Logit analysis allows estimation of the probability of success (e.g., the probability of earning tenure) after controlling for differences in individual characteristics among doctorate recipients included in the sample. Outcomes for the tenure and tenure-track analyses are discrete binomial occurrences in that only two outcomes are possible—tenure or not tenured, and on tenure track or not on tenure track. Outcomes for the analysis of academic rank, however, are multinomial in that several outcomes are possible—full professor, associate professor, or junior rank.

CONTROL VARIABLES

Table 2-1 lists the control variables included in the Phase I analyses. These include human capital proxies, personal characteristics, family characteristics, female interactions, year of the survey wave, and selection variables related to employment. In addition to the listed controls, each of the Phase I analyses includes a dichotomous (dummy) variable distinguishing females from

[1] The SDR is longitudinal in the sense that individuals reappear in successive survey waves throughout their careers as long as they remain in the sample frame. The SDR data are not maintained in a longitudinal format, however, so constructing employment and family histories for individuals requires linking survey identification numbers across SDR waves.

males. The estimated coefficient on the "female" variable allows us to compute gender differences in the probability of a career success after accounting for the effects of controls.

Human Capital

Other things being the same, individuals who have accumulated more human capital are more likely to have earned tenure and to have been promoted to higher academic ranks. Table 2-1 lists human capital variables used as controls in the Phase I analyses. We emphasize that these variables are not direct measures of human capital; rather, they should be interpreted as proxies.

We included "years since earning the doctorate" as a measure of postdoctoral experience. We also included a set of variables distinguishing between the kinds of financial support that doctoral candidates receive in graduate school. We interpret these variables as proxies for differences in experience and training and differences in academic ability. For example, those who earned the doctorate while supported by research assistantships are likely to have experience and training different from that of doctoral candidates who were supported by teaching assistantships. And doctorate earners who were supported by fellowships are likely to be more academically able than those who received other kinds of support.

TABLE 2-1. Phase I control variables by category

Human capital
Years since earning the doctorate
Kind of graduate support (fellowship, research assistantship, teaching assistantship, traineeship, other)
Time-to-degree (years between bachelor's degree and doctorate)
Postdoctorate plans (planning postdoctorate appointment)
Field switching (between degrees)
Bachelor's degree earned at foreign institution
Doctorate earned at research institution
Doctorate earned at public institution
Academic field (usually 17 fields distinguished, but some fields combined for rank models)
Personal characteristics
Age when doctorate was earned
Citizenship (naturalized, permanent resident, temporary resident, other)
Race/ethnicity (American Indian/Alaskan Native, Asian/Pacific Islander, black, Hispanic, other)
Family characteristics
Marital status
Number of dependents younger than 6
Number of dependents age 6 to 18
Female interactions
Marital status at time of survey
Number of dependents younger than 6
Number of dependents age 6 to 18
Survey wave, 1981–1997
Employment selection
Primary work activity (research, teaching, other)
Carnegie classification of employer (doctoral, research, other)
Employed at private institution

Some doctorate earners opt for additional training by taking postdoctoral appointments before they enter the full-time academic labor market. Our list of controls includes a variable reflecting whether individuals were planning postdoctoral appointments at the time they received their doctorates. The potential effect of this variable is an empirical issue. Postdoctoral appointments afford individuals opportunities for additional training that might improve chances for success in academia, but they delay entry into full-time faculty positions and thus can delay tenure and promotions to higher academic ranks.[2]

Field switching occurs when individuals earn undergraduate degrees, masters' degrees, or doctorates in different academic fields. Expertise in two or more fields could enhance chances for success in academic careers. Alternatively, individuals who stay in a single field might realize benefits from specialization that also affect career outcomes.

We included three variables that distinguish characteristics of the institutions at which individuals earned degrees—earning a bachelor's degree at a foreign institution, earning a doctorate at a research institution, and earning a doctorate at a public institution. Although these variables distinguish possible differences in accumulated human capital, we regard their effects on success in academic jobs as an empirical issue.

Chances for earning tenure and promotion are likely to vary considerably across different academic fields. We included a set of control variables that distinguish 17 different fields in which individuals earned their doctorates. These fields are identified in table 2-2.[3]

[2] Postdoctoral appointments could also reflect selection by ability. For example, the most able doctoral candidates might be more likely to receive faculty appointments immediately after earning their degrees.

[3] Identifying the parameters of the logit models required us to combine a few of the fields in table 2-2 for the academic rank analyses. See Appendices C and D.

Personal Characteristics

Table 2-1 lists three sets of control variables reflecting the personal characteristics of doctorate recipients—age at the time the doctorate was earned, citizenship, and race/ethnicity. We included these variables as controls to capture variations in backgrounds, opportunities, and preferences that could affect chances for tenure and promotion.

Family Characteristics

We included a set of three "family" variables as controls in the Phase I analyses. These are marital status (married or unmarried), the number of dependent children less than 6 years of age, and the number of children between the ages of 6 and 18.

Family characteristics can reasonably be expected to influence chances for tenure and promotion, but the direction of their effects is unclear. For example, being married might enhance a doctorate recipient's career if the spouse provides support and motivation. Having children might also provide motivation. Alternatively, the burden of supporting a family might divert time and energy from job responsibilities, thus reducing chances for tenure and promotion.

The ages of a doctorate recipient's dependent children convey information for estimating the effects of family composition on career success.[4] Three potentially important effects are (1) differences in child-rearing requirements, (2) cumulative care-giving effects, and (3) fertility timing. Children of different ages require different kinds and levels of care. Children of pre-school age, for example, require very different kinds of care than do children of high-school age. Also, older children have required a period of parental care longer than that required by younger children. For example, a two-year-old child has required care for only 20 percent of the time that a 10-year-old child has. Ages of children also convey information about the timing of fertility decisions. For example, an individual with 10 years of postdoctoral experience who is caring for a two-year-old child has likely postponed starting a family until after the time academic institutions typically make tenure decisions. An individual with the same experience and a 10-year-old child has probably been faced with child-rearing responsibilities before receiving tenure. This discussion points to the importance of measuring family composition at comparable times in the careers of doctorate recipients. For example, a two-year-old in the family of an individual with six years of experience might have a quite different effect on career success than would a two-year-old under the care of an individual with 10 years of experience.

[4] Over the period 1981–1997, the SDR survey instruments have solicited different information about dependents' ages. The distinctions we make—children under age 6 and children between the ages of 6 and 18—reflect the most detail consistently available since the 1981 SDR wave.

TABLE 2-2. Doctoral fields included in tenure and rank analyses

Academic field	Specialty codes[1]
Agricultural science	0–99
Biological science	100–199
Health science	200–299
Chemical engineering	312
Electrical engineering	322–324
Other engineering	300–311, 313–321, 325–399
Computer and information sciences	400–410
Mathematics	420–499
Physics and astronomy	560–576, 500–505
Chemistry	520–539
Geosciences	510–519, 540–559, 585–595
Other physical sciences	580–599
Psychology	600–649
Economics	666–668
Political science	678
Sociology, anthropology, and demography	686, 662, 650
Other social sciences	652–658, 670–682, 690–699

[1] Codes match those used in Survey of Earned Doctorates.

Family characteristics might also affect chances for career success indirectly by affecting job choices. Doctorate recipients with spouses and children face location constraints that unmarried doctorate recipients without children do not. These constraints might cause individuals to compromise job choices and, eventually, reduce their chances for tenure and promotion.

We close this discussion with an important caveat about the difficulty in assigning causal links between family composition and career success. It could be that both marital status and timing of fertility are influenced by doctorate recipients' expectations of chances for tenure and promotion. Evidence from the literature suggests that women who perceive gender bias are more likely to marry and to have children earlier than they might otherwise (NSF 2003). To the extent that this occurs, observed relationships between family variables and career success will partly reflect selective decisions by individuals who believe their chances for tenure and promotion are relatively low.

Female Interactions

Some of the models we estimated include three female-interaction variables. These are interactions between "female" and marital status, "female" and the number of children younger than 6, and "female" and the number of children between ages 6 and 18. We included these variables to measure possible gender differences in the effects of family composition on chances for tenure and promotion.

There are several reasons to think that family composition might affect the academic careers of women and men differently. Gender differences in household and child-rearing activities could give rise to differential effects. If women, as a group, tend to undertake more household and child-rearing responsibilities than men do, they will have less time and energy to devote to their careers.

The constraint that marriage imposes on job choices might also be expected to differ by sex. Because academic job openings are limited, households in which both spouses seek faculty jobs face especially difficult location decisions, which often require compromise. Men and women both face this compromise in families where both spouses hold doctorates. But because fewer women than men have doctoral degrees, men are less likely than women to have their job choices constrained owing to their spouse also holding a doctorate.[5]

Survey Wave

Changes in labor market conditions and promotion requirements over the 1981–1997 time period spanned by our data are likely to affect success rates for academic careers. Accordingly, we controlled for the survey year in which individuals are observed in the data.

Employment Selection

Variables for employment selection reflect either voluntary or involuntary selections made by doctorate recipients about the kinds of activities they undertake on the job and the characteristics of the institutions at which they are employed. Relationships between the selection variables and career success rates should be interpreted cautiously. Because the selection variables themselves are career outcomes, they could be determined by the same forces—gender bias and other gender-specific factors—that affect tenure and promotion decisions. For example, if women as a group tend to emphasize teaching as a primary work activity because there is gender bias against women in research, controlling for primary work activity in the tenure analysis might mask gender differences in tenure rates. Because of this potential problem, we adopted the convention of conducting each of the Phase I analyses twice—with and without the selection variables as controls.

Phase I Sample Restrictions and Model Specifications

This discussion provides a framework for interpreting the results of the Phase I analyses presented later in this report. It includes restrictions imposed on the samples used for estimating the tenure, tenure track, and academic rank models; specifications of the models we estimate; and guidance for interpreting results.

Sample Restrictions

Data for the Phase I analyses were from the 1981–1997 SDR waves. All Phase I analyses were restricted to those doctorate recipients who reported full-time employment in academia; however, the samples we used were further restricted. These sample-selection criteria were years since earning the doctorate, outcome not applicable, not on tenure track, and missing observations.

Years Since Earning the Doctorate

Each of the Phase I analyses is based on a sample of doctorate recipients selected by postdoctoral experience (the number of years elapsed since earning the doctorate). Both the tenure track and tenure analyses were conducted using two different samples characterized by years of experience: one sample restricted to individuals with 8 or 9 years of postdoctoral experience, and a second sample restricted to individuals with 14 or 15 years of experience. The academic rank analysis was also conducted using two different samples: a first sample restricted to individuals with 14 or 15 years of experience, and a second sample restricted to individuals with 20 or 21 years of experience.

[5] One might argue that dual-career families have financial resources that enable them to sacrifice current income for positions that offer better career opportunities. This possibility, however, poses difficult modeling issues. Even if data on spouses' education and income were available, it would be unclear whether the selection of a position with lower pay but better opportunities for career advancement was permitted by the spouse's income or whether it resulted from a location compromise.

Each analysis includes a sample selected by an even-numbered year and an adjacent odd-numbered year. We used this selection procedure to exploit fully the sample sizes available in the SDR. Given that the SDR is conducted every other year, selecting by a single year (say, only even-numbered years) would yield only about one-half the available sample.

Our principal motive for selecting samples by years since the doctorate was earned was to ensure that the time-dependent control variables were observed at about the same point in each individual's postdoctoral career. The most important of these are the family and female-interaction variables. Selecting samples by years of experience also ensured that the selection variables characterizing work activities and employers were also observed at about the same time in postdoctoral careers.[6]

Ensuring that individuals appear in a given sample only once was a second motive for selecting by years of experience.[7] This avoided problems associated with uneven weighting (doctorate recipients with more experience appear in more SDR waves than those with less experience) and correlated statistical errors across individual observations.

Outcome Not Applicable

When asking individuals to report on tenure and rank status, the SDR survey instruments permit "not applicable" responses. Some of the analyses we conducted use samples that exclude individuals who made "not applicable" responses. This allowed us to determine the extent to which "not applicable" job assignments (which might be involuntary) explain differences in tenure and promotion rates.

Nontenure-Track Positions

The SDR survey instruments also allow respondents to report that they are employed in "not on tenure track" positions. Again, we conducted some tenure and rank analyses excluding these individuals to determine the extent to which assignments to nontenure-track positions explain gender differences in career success rates.

Missing Observations

Some SDR respondents do not complete the questionnaire. We excluded from our analyses doctorate recipients who did not report on tenure and rank status.[8]

Model Specifications

We estimated six models for each of the Phase I tenure and academic rank analyses (table 2-3). Comparisons across these six models allowed us to determine whether selection variables (primary work activities and employer characteristics), assignments to job positions in which tenure or academic rank are not applicable, and assignments to nontenure-track positions affect estimates of gender differences in success rates.

TABLE 2-3. Phase I models and criteria included

Model	Outcome not applicable	Not on tenure track	Selection variables
1	Yes	Yes	No
2	Yes	Yes	Yes
3	No	Yes	No
4	No	Yes	Yes
5	No	No	No
6	No	No	Yes

Model 2, for example, differs from Model 1 in that it includes selection variables as controls.[9] Thus, by comparing estimates of gender differences across these two models we could determine whether work activities or employer characteristics explain some of the observed gender differences in career success rates. Models 3 and 4 and Models 5 and 6 are paired in the same respect.

Models 1 through 4 differ only in the treatment of "not applicable" responses. Thus, by comparing estimates of Models 1 and 2 with those of Models 3 and 4 we could determine if "not applicable" job assignments affect estimates of gender differences in outcomes.

Finally, Models 5 and 6 exclude individuals who reported being in nontenure-track positions. These two models allowed us to determine the extent to which as-

[6] Selecting samples based on years of postdoctoral experience does not resolve timing issues related to predoctoral careers. Before earning their doctorates, some individuals accumulate human capital and credentials that might enhance their postdoctoral academic careers. The data we used provides no information about individuals' work histories before they earned doctorates; however, some of the effects of predoctoral careers are likely to be captured by controls for age and academic field. Older doctorate recipients are more likely to have accumulated predoctoral experience, and the extent to which predoctoral credentials affect academic careers is likely to vary by field. In our analyses, we controlled for both age and field.

[7] Once individuals are selected for the SDR, they are followed in subsequent waves as long as they remain in the sampling frame. As a result, the same individual can appear in several SDR waves.

[8] We did not exclude individuals when the value of a control variable was missing. Instead, we constructed dichotomous (dummy) variables for missing control variables.

[9] All six models include the other controls listed in table 2-1.

signments to nontenure-track positions affect estimates of gender differences.[10]

We estimated each of the models listed in table 2-3 twice, with and without the female-interaction variables. By comparing the two sets of results we could determine how gender differences in the effects of family characteristics affect gender differences in tenure and promotion rates.

Phase II Study Design

Several aspects of the Phase II analyses are distinctly different from the Phase I analyses. Below we describe the Phase II study design.

Career Outcomes

The Phase II analyses examine tenure and academic rank for doctorate recipients who reported full-time academic employment. Unlike Phase I, Phase II does not include a formal analysis of tenure-track status. The Phase II analyses look at the time required for a clearly defined transition from one state to another in a career path (e.g., nontenured to tenured).

Statistical Models

We used multivariate hazard analysis as the principal statistical tool in the Phase II analyses.[11] Hazard analysis looks at the time required for a transitional event to occur (e.g., time elapsed between earning the doctorate and earning tenure). Estimates of hazard models provide information needed to compute the probability that an individual will be tenured or promoted to senior academic ranks at a given point in time.[12] Like Phase I, the Phase II analyses are multivariate in the sense that we compared career success across gender after controlling for other factors that might affect tenure and promotion.

Estimating the hazard models for the tenure analysis required the following information: the time elapsed between earning the doctorate and receiving tenure for those individuals who have been tenured (at or before the 1997 SDR wave); the time elapsed between earning the doctorate and the 1997 SDR wave for those individuals who have not received tenure; and a censoring indicator distinguishing those individuals who have received tenure from those who have not.

Phase II analyses include doctorate recipients who were employed full time in academia as of the 1997 SDR wave. We constructed a variable measuring time elapsed between earning the doctorate and earning tenure by searching previous SDR records (i.e., SDR waves before 1997) for the first occurrence of reported tenure.[13] Then, we took the date of the first reported occurrence as the date of tenure and counted years elapsed since the year of the doctorate. If no SDR wave indicated tenure, we assumed that the individual had never been tenured and counted years elapsed between earning the doctorate and the 1997 survey wave.

The Phase II academic rank analysis required the same kind of information as the tenure analysis. Of course, the rank analysis required data on the time elapsed between earning the doctorate and promotion to either associate or full professor. We constructed these variables using the same method described above for the tenure analysis.

The method we used to create measures of time elapsed before tenure or promotion introduced a potential bias. Specifically, we overstate time required to achieve tenure or promotion if those outcomes are not reported in the survey that corresponds to the date of the outcome. For example, suppose that an individual was first tenured as of the date of the 1993 SDR but failed to complete the section of the 1993 questionnaire on tenure status. Suppose further that the same individual reported being tenured on the 1995 survey. Our method will overstate time required for tenure by two years for this individual.[14]

We have compared missing responses to survey items on tenure and rank status for men and women in our sample. We found that women are about 3.5 percent less likely than men to have missing observations for these outcomes before they become tenured or promoted to

[10] Because Models 5 and 6 include only doctorate recipients in tenure-track positions, they could not be estimated for the analysis that examines gender differences in tenure-track placements.

[11] Hazard analysis is sometimes referred to in the literature as duration or survival analysis.

[12] See Appendix A for a more detailed discussion of hazard analysis.

[13] Unfortunately, the SDR data report whether individuals are tenured as of each survey but do not report the date of tenure. The same is true for academic rank.

[14] The SDR questionnaire simply asks whether an individual is tenured as of the date of the questionnaire; it does not ask when tenure was received.

the rank of associate professor.[15] This raises the possibility that we overstate time required for tenure and promotion for men relative to women, or equivalently, that we understate relative differences in male to female success rates. Unfortunately, we cannot tell for certain whether the bias exists, and if it does, the extent to which it occurs.[16]

Control Variables

Like Phase I, the Phase II analyses are multivariate in that we attempt to measure gender differences in career success rates after accounting for factors other than sex that might affect tenure and promotions. All of the Phase II analyses also include the dichotomous variable "female," which distinguishes female from male doctorate recipients. The estimated coefficient of the female variable serves the same purpose in Phase II as it does in Phase I.

Table 2-4 lists the control variables used in the Phase II analyses. The human capital variables and personal characteristics are the same as those used in Phase I and are not discussed further here.

Family Characteristics

The family variables used in Phase II—marital status, dependents younger than 6, and dependents between ages 6 and 18—are the same as those used in Phase I. When we measure them, however, is slightly different. For Phase II, we measured family variables three waves (about 6 years) and six waves (about 12 years) after the doctorate was earned for the tenure and the academic rank analyses, respectively. For the academic rank analysis, we measured family variables later in postdoctoral careers to coincide more closely with the time at which promotion to full professor might occur.

Female Interactions

The Phase II analyses include the full set of female-interaction variables. Our reasons for including these as controls are the same as those described earlier for the Phase I analyses. We defined the female interactions so that they are observed at the same time in the postdoctoral career as the family variables.

[15] Gender differences in missing outcomes before promotion to the full professor rank are small and are statistically insignificant.

[16] The bias occurs only if the individual fails to respond to questions of tenure and rank status on the first survey wave after either tenure or promotion actually occurs.

TABLE 2-4. Phase II control variables by category

Human capital
Kind of graduate support (fellowship, research assistantship, teaching assistantship, traineeship, other)
Time-to-degree (years between bachelor's degree and doctorate)
Postdoctorate plans (planning postdoctorate appointment)
Field switching (between degrees)
Bachelor's degree earned at foreign institution
Doctorate earned at research institution
Doctorate earned at public institution
Academic field (usually 17 fields distinguished, but some fields combined for rank models)
Personal characteristics
Age when doctorate was earned
Citizenship (naturalized, permanent resident, temporary resident, other)
Race/ethnicity (American Indian/Alaskan Native, Asian/Pacific Islander, black, Hispanic, other)
Family characteristics
Marital status
Number of dependents younger than 6
Number of dependents age 6 to 18
Female interactions
Marital status at time of survey
Number of dependents younger than 6
Number of dependents age 6 to 18
Decade of doctorate, 1970s–1990s
Selection[1]
Outcome status not applicable
Employment status
Not working full time in academia
Working at research institution
Working at doctoral institution
Primary work activity research
Primary work activity teaching

[1] Percentage of survey waves with listed response before tenure or promotion achieved.

Decade of the Doctorate

The Phase II analyses include a set of dichotomous variables that identify the decade (1970s, 1980s, 1990s) in which individuals earned their doctorates. We included these variables to control for changes over time in labor market conditions and tenure and promotion requirements.[17]

Selection Variables

The Phase II analyses include two kinds of selection controls—an outcome-status variable and several work-history variables. We refer to these as selection variables because, as outcomes themselves, they are determined by either voluntary self-selection or involuntary assignment.

[17] Because the Phase I analyses control for year of the survey wave and time since earning the doctorate, controlling for the year of the doctorate as well would be redundant.

Although several of the Phase II selection variables listed in table 2-4 are similar to those used in Phase I, their construction is quite different. The Phase I selection variables are a snapshot of the individual's status at the time of the survey wave. The Phase II selection variables are more informative because they reflect work histories that track the individual's status between when the doctorate was earned and either tenure or promotion (or time elapsed up to the 1997 SDR wave if the individual has not been tenured or promoted).

We constructed the Phase II selection variables using a method similar to the procedure for computing time elapsed between earning the doctorate and achieving either tenure or promotion. Specifically, we traced each individual appearing in the 1997 SDR wave through earlier waves, counted the number of times before tenure or promotion that the individual reported being in a given status, and calculated the percentage of survey waves for which that status was reported. For example, if an individual reported employment status in four waves before being tenured and in one case reported employment outside academia, the variable reflecting "not working in academia full time" takes on a value of 25 percent for the Phase II tenure analysis.

The variable "outcome status not applicable" measures the percentage of survey waves before tenure or promotion that an individual reports employment in a position in which either tenure or academic rank is not applicable. Other factors being the same, we would expect this variable to be positively correlated with time elapsed before tenure or promotion (or negatively related to the probability of being tenured or promoted at a given point in time).

The set of work-history variables includes a measure of the percentage of survey waves before either tenure or promotion that an individual reports not being employed full time in academia. In most cases, we would also expect this variable to be positively correlated with time elapsed before tenure or promotion.[18]

The remaining four work-history variables reflect the characteristics of employers and primary work activities. These variables coincide with selection variables used in Phase I, except that they reflect employment histories rather than current employment status.

Phase II Sample Restrictions and Model Specifications

Sample Restrictions

The Phase II analyses used a selected sample of the doctorate recipients who reported full-time academic employment in the 1997 SDR wave. The analyses for tenure and promotion to associate-professor rank include only individuals with 6 or more years of postdoctoral experience; the analysis of promotion to full professor includes only individuals with 12 or more years of postdoctoral experience. Doctorate recipients whose years of postdoctoral experience fall below these limits were excluded from the analyses.

These exclusions principally were made to allow us to measure the variables for family and for female interactions for each individual at a comparable time, close to when tenure and promotions occur in a typical academic career. Family variables are undefined (not yet observed) for these less-experienced doctorate recipients because they have not yet reached the later career points being measured.[19]

Secondarily, the sample exclusions are motivated by censoring effects. Observations for less-experienced doctorate recipients are heavily censored in that very few individuals receive tenure in less than 6 years or are promoted to full professor in less than 12 years. Although hazard analysis is designed to deal with censoring effects, including the less-experienced doctorate recipients in our samples would provide little information about career success rates.

Model Specifications

Table 2-5 lists the Phase II model specifications. These models allowed us to determine whether the selection variables reflecting work histories affected estimates of gender differences in career success rates. For example, Models 1 and 2 differ in that the latter includes variables for work history. Comparing estimates of these two models allowed us to determine whether

[18] Some individuals might acquire skills or experience in employment outside of academia that enhance their chances for success in academia, but we expect in most cases a history of full-time academic employment would allow individuals to acquire job-specific human capital that would confer greater advantages in the academic labor market.

[19] For example, we do not observe family characteristics six years after earning the doctorate for individuals reporting only two years of postdoctoral experience in the 1997 survey.

TABLE 2-5. Phase II models and criteria included

Model	Outcome not applicable	Employment-related variables
1	No	No
2	No	Yes
3	Yes	No
4	Yes	Yes

estimates of gender differences in success rates are sensitive to employment-related histories. Similarly, Models 3 and 4 differ from Models 1 and 2 in that the latter include the variables reflecting time spent in outcome-not-applicable job positions.

Contributions to the Literature

We have reviewed several statistical studies of gender differences in academic careers (NSF 2003). Some of these studies are similar to ours in that they used multivariate analyses, used data from nationally representative samples, and included broad coverage of academic fields. Our study design, however, offers three important contributions to the literature. These are our treatment of family characteristics, systematic control for selection variables, and the longitudinal nature of our Phase II analyses.

Family Characteristics

Relatively few studies provide evidence on the effects of family characteristics on women's academic careers. Farber (1977), McDowell and Smith (1992), and Kahn (1993) provided suggestive evidence that family responsibilities hinder women's careers in that women appear to be disadvantaged at points in their careers when they are likely to have young children.

Two studies, Long (2001) and Olson (1999), included direct controls for family characteristics in their analyses of tenure and promotions. Both, however, estimated separate models for men and women, and neither conducted formal hypothesis testing of differential gender effects. Moreover, both Long and Olson measured family characteristics at different points in the careers of doctorate recipients included in the data. As we have argued, it is reasonable to expect that the timing of both marital and fertility decisions are important.

We have attempted to resolve both issues with our study design. First, our specification of the female-interaction variables permits straightforward hypothesis tests for gender differences in the influence of family characteristics on academic careers. Second, we have been careful to measure family characteristics at common points in postdoctoral careers in both our Phase I and Phase II analyses.

Selection Controls

Some of the studies we have reviewed include variables reflecting the characteristics of the employing institution as controls (NSF 2003). This kind of model specification is understandable, given that requirements for tenure and promotion are likely to vary across different kinds of institutions. For example, it is reasonable to expect that tenure and promotion requirements are usually more stringent at research universities than at most four-year liberal arts colleges. Nonetheless, we have concerns about interpreting estimates of gender differences in career success rates from models that control for employer characteristics. The problem is that the characteristics of the employer are themselves outcomes resulting from a selection process that may be affected by factors related to career success, including individual preferences, human capital, opportunities, and real or perceived gender bias.

These same comments apply to primary work activities. Decisions to engage in research or teaching, which are likely to affect career success, result from a selection process reflecting preferences, skills, and opportunities. If women are disadvantaged with respect to tenure and promotion, they may also be limited in their choices of work activities.

Our study design does not completely resolve the problems associated with using selection variables as controls. However, the sequence of models we estimated includes specifications both with and without employer characteristics and primary work activities. As we noted earlier, this feature of our study design allowed us to determine whether estimates of gender differences in career success rates are sensitive to model specifications that include selection variables as controls.

Longitudinal Controls

Many of the studies we have reviewed use multivariate analyses in that they attempt to estimate gender differences in career success rates after accounting for controls. However, because these studies measure controls for each individual at only a single point in time, they cannot account for the potential effects of career histories on outcomes. We have attempted to resolve this problem in our Phase II analyses. Some of the models we estimated include work-history variables as controls.

These include variables measuring the percentage of time before tenure and promotions that individuals spent working outside of academia, working for employers with various characteristics, and engaging in different work activities.[20]

Study Limitations

Several important limitations of our study design should be considered when interpreting the results of our analyses, which are presented in later sections of this report. In particular, our results do not prove the presence or absence of gender bias in academia; rather, the study's findings should be interpreted within the broader context of the empirical literature on gender differences in academic careers.

Potential Selection Bias

The potential for selection bias is perhaps the most serious limitation of this study. Doctorate recipients included in our analyses were not randomly assigned to the samples we used. Individuals included in the sample were those who selected science or engineering as a field of study and who completed requirements for a doctorate. They also selected and obtained a full-time position in academia rather than a part-time academic position or employment in a nonacademic job. The selection process itself, however, may be determined in part by differences in individual preferences or by discriminatory treatment that could be related both to sex and to chances for career success. Although we attempted to control for differences among individuals in our analyses, we were limited to characteristics that are measurable and available in the data we used. As is typically the case in empirical work, we could not control for remaining unobserved differences among individuals that could affect outcomes. These unobserved differences could be related to sex and the selection process, thus raising the possibility of selection bias.

There are also selection issues related to the samples we have chosen to use, which exclude doctorate recipients employed part time in academia. A selection issue arises if, other factors being the same, women are more likely than men to work part time. Also, because we limited our samples to doctorate recipients employed in academia, we did not account for attrition from the academic workforce. The selection issue here is whether women are more likely than men to remain in academia if they fail to land tenure-track positions, receive tenure, or earn promotions.

Statistical methods for adjusting for selection bias have been developed.[21] The data required to adjust for some of the potential sources of bias described above, however, are unavailable in the samples we used. For example, adjusting for selection into science and engineering fields requires information on individuals who have selected fields other than science and engineering. Similarly, adjusting for selection into the sample of doctorate recipients requires data on individuals who have not earned doctorates. This information is not available in the data we used.

In theory, the data required to adjust for selection into full-time academic positions are available, given that the SDR data include some doctorate recipients who hold nonacademic jobs and some who are employed part time. However, estimating models that adjust for selection bias requires a priori identification restrictions on factors affecting job choices and tenure and promotions. Given the choices of variables available in the data we used, appropriate identification restrictions were not obvious to us.[22]

Limited Controls

Although the multivariate analyses we conducted account for a relatively large set of factors other than gender that might affect career success, the controls we could use were necessarily limited by the data available to us. For example, the variables for human capital we included in our models are proxies, not direct measures of skills and abilities that might enhance doctorates' chances for tenure and promotion. Also, our analyses did not control for variations in measures of productivity, which include scholarly output, quality of teaching, and service to the academic community.[23] Finally, we had limited information about individuals' predoctoral careers.

[20] Note that the work-history variables can be viewed as selection variables in the sense that they result from a selection process that could be affected by the same factors that influence tenure and promotion.

[21] See, for example, Heckman (1974, 1976).

[22] The identifications restrictions require that different sets of factors influence job choices and tenure or promotion outcomes.

[23] The 1995 SDR is the only wave that provides information on scholarly output (the number of articles published and papers presented). However, the sample size for the 1995 wave alone is too small to estimate the models we specify. None of the SDR waves provides data on teaching quality or service to the academic community (e.g., committee assignments).

Some information about predoctoral education was available, but we had no information about predoctoral work experience.

Potential Reporting Bias

We may systematically overstate the relative time required for male tenure and promotions in our Phase II analyses because of missing responses in the SDR data (see “Phase II Control Variables,” above). We have evidence that women are more consistent than men in completing the SDR questionnaires. Women are about 3.5 percent less likely than men to have omitted information on their rank before they achieved tenure and promotion to associate professor, and they are about 3.0 percent less likely to have omitted this information before they achieved promotion to full professor.[24] This raises the possibility that the Phase II analysis overstates the relative time required for men to achieve promotions. To the extent that this occurs, our estimates of female disadvantages in the Phase II analyses will be understated.

Future Research

This study focuses on gender differences for a limited set of career outcomes, but the available data are suited to address several other important questions about the academic careers of female scientists and engineers. These include such questions as whether among scientists and engineers women are more or less likely than men to take academic jobs, take part-time employment in academia, or remain in academia, especially after failing to receive tenure and promotions, and whether women face greater mobility constraints than men when selecting jobs, especially when they must find new employment after failing to receive tenure.

Several of our recommendations for future research address some of the previously noted limitations of this study. For example, we noted that gender differences in preferences for academic versus nonacademic jobs raises the potential for selection bias. A study of gender differences in job choices—especially the first job after earning the doctorate—would help us assess the potential for selection bias. Studies of gender differences in full-time versus part-time employment and in attrition rates would also address selection issues.

A job-mobility study might shed light on whether immobility compromises the academic careers of female scientists and engineers. We are particularly interested in whether gender differences in mobility exist among doctorate recipients who fail to receive tenure in their first academic job. Many doctorate recipients who take first jobs at prestigious research institutions fail to earn tenure. Their ability to earn tenure at a subsequent position is likely to depend on the freedom they have to choose jobs that are well suited to their experience and skills.

This study provides evidence that gender differences in the influence of family variables—marital status and family size—are related to women’s chances for career success. Accordingly, we recommend that future studies be designed to control for potential gender differences in the influence of family characteristics.

[24] The gender difference in response rates for the associate-professor analysis is statistically significant. Even though the difference for the full-professor analysis is not statistically significant, there is still potential for bias in the measure of time to promotion.