

Author and year	Method and target group	Findings and comment
Yin, Merchlinsky and Adams-Kennedy (1998)	Survey and case studies, comparison group  7 pilot centers (receiving \$750 000 over 3 years to establish a manufacturing SBDC) and 7 comparison centers with SBDC relationships but no special funding	Pilot and comparison centers did not differ markedly either in the nature of their partner relationships with SBDC or in the seamlessness of their service delivery
Youtie and Shapira (1997)	Customer survey – longitudinal tracking study  Georgia, MEP customers	68% assisted firms took action, with more than 40% per cent reporting reduced costs, 32% improved quality, 28% capital investment. Customers overestimate benefits and underestimate costs close to point of survey, except for small number of high-impact projects

Source: Youtie and Shapira (1998), updated.

In. Philip Shapira and Stefan Kuhlmann, Eds. 2003. *Learning from Science and Technology Policy Evaluation: Experiences from the United States and Europe*. Cheltenham, UK: Edward Elgar. Pp. 293-315.

## 15. Evaluating the impacts of grants on women scientists' careers: the curriculum vitae as a tool for research assessment

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### INTRODUCTION

Few public policies aim to affect women scientists and there are few scholarships, fellowships, and targeted grants funding. Unlike some fields of social legislation, including legislation affecting women, policies pertaining to women scientists do not seem to have been much informed by research or policy analysis. The policy mechanisms have been straightforward and their assumptions simple: provide women with resources and they will flourish, or at least will flourish so long as they are protected by the soft shield of anti-discrimination legislation.

In our view, the assumptions behind policies for women scientists need greater scrutiny. While it certainly seems reasonable, for example, that women scientists will thrive if provided a greater share or magnitude of research grants, it does not follow that all fields are in equal need of redress, that all occupational levels have the same needs, or that research grants are unidirectional in their effects. Our chapter examines the impacts of grants on the scientific careers of scientists, comparing a sample of male and female scientists, all working in US universities, most of them working in interdisciplinary science centers.

We feel that systematic assessment of differential effects of grants and science resources on men and women deserves more attention from research evaluators, especially in an era in which scientific talent is in short supply in the industrialized world. When foreign scientific talent is being imported at a

furious pace, women's increasing interest in science and engineering careers is not just a positive development, it is potentially a matter of national competitive advantage. Nations failing to exploit the scientific talent of half their population will have an extraordinarily difficult time competing in technologically intensive global economies.

Despite the importance of evaluating policies affecting scientists' careers, no new means of doing so has emerged during recent years. Most studies of scientists' careers are still rooted in problematic cross-sectional regression. This is unfortunate because few phenomena so obviously require longitudinal methods. Not much can be learned about career trajectories by simply evaluating a chronological snapshot. A particular feature of this study is a research evaluation methodological innovation. Our data source is one with which academics and evaluators could hardly be more familiar, but data not usually thought of as a rich lode to be mined by researchers. For 1061 scientists we employ an obvious but surprisingly underutilized data source: the curriculum vitae (CV) (see Dietz et al. 2000, for a discussion of the methodological implications of using CV data). We use CVs to examine the effects of research grants on women scientists' career trajectories and productivity, but the result should also show that CVs have broad applicability to a range of research evaluation questions. The statistical approach we use is also uncommon in research evaluation. We employ hazard models and event history analysis, techniques used commonly in demography, to consider some of the longitudinal issues of career trajectories.

Since we are concerned that public policy for women scientists does not seem much informed by the research literature, we provide an overview of empirical studies, returning in the conclusions to these studies findings, as well as our own, to consider the question: 'What are the implications for public policy for women scientists?'

#### STUDIES OF WOMEN SCIENTISTS' CAREERS

The empirical literature on the productivity and career success of women scientists continues to show that women lag behind in productivity, especially when measured by publications, in time-to-tenure, and in promotion. Since there is good evidence that men and women begin with quite similar human capital endowments, it seems to us that there are four plausible explanations of consistent findings of women's lesser productivity: (1) poor, invalid, or out-of-date studies; (2) lesser opportunities for women as compared to men (including continued discrimination and fewer resources); (3) different life and career choice structures for women and men; (4) and mis-specified notions of 'success and productivity'. We cannot provide evidence on all of

these points, but we do consider the issues of previous studies' limitations and differences in opportunity structures. Our particular concern is to examine women scientists and engineers' career trajectories, over the span of the career, rather than focus, as have previous studies, on cross-sectional productivity data.

The subject of women's careers in science is located at the intersection of two fields: the sociology of science and the sociology of gender. The result of this meshing of two fields has led to the development of two models that attempt to explain why women are less likely than men to succeed in science: the deficit model and the difference model (Sonnert, 1995a). While the deficit model attempts to explain why women are treated differently in science, the difference model attempts to explain why women *act* differently in science.

According to the deficit model, women generally receive fewer chances and opportunities than do men throughout the course of their careers. This model assumes that men and women have similar career goals, but barriers to advancement hinder women from accomplishing career goals that are equivalent to the goals that men reach. Therefore, the deficit model criticizes the barriers that are created as a result of legal, political, and social structural obstacles that exist within the social system of science. As a result, the deficit model typically blames formal gender discrimination for the lagging success that female scientists typically experience in the workplace. Even though many of the formal structural barriers that hinder women in science were banned in the 1970s and 1980s, the social system of science still supports many informal structural barriers to female scientists (Sonnert, 1995a). From 200 interviews with female and male academic scientists, Sonnert (1995a) found that 73 per cent of the female scientists had experienced sex discrimination in their careers and only 13 per cent of the male scientists had experienced reverse discrimination. Of the women interviewed, 22 per cent said that discrimination had been a career obstacle. Even though blatant gender discrimination might be on the decline in the United States, it remains prevalent enough that according to Sonnert, 'a woman entering the field now should be aware that at some point in her career she might encounter behavior that she will consider gender discrimination' (1995a, 139).

In contrast to the deficit model, the difference model states that female scientists tend to be less successful than male scientists because of intrinsic differences between the career goals of men and women. While the deficit model focuses on external, structural obstacles to the advancement of women in science, the difference model focuses on internal obstacles. The difference model argues that these internal obstacles are either innate or the result of gender-role socialization. In summary, the difference model argues that women and men have different career paths because the two genders are inherently different. Sonnert (1995a) asked male and female scientists to rate

themselves on socialization patterns and personality traits. They found that the results for men and women were indeed different. More men than women reported that they considered their scientific ability to be above average (70 per cent compared to 52 per cent). Also, more men than women felt that their colleagues rated their scientific ability as above average (70 per cent compared to 53 per cent). In the areas of assertion and self-confidence, men won out again. More men than women considered themselves to be self-confident (58 per cent compared to 49 per cent). With regard to assertion, many more women than men thought that they should have handled their career obstacles with more confidence and assertion (25 per cent compared to 5 per cent).

However, it is unlikely that these gender personality differences are the cause of women's average career lag behind men (that is, the difference model); rather, the gender differences might be the end result of women's greater career obstacles and subsequent relative lack of success (that is, the deficit model). Therefore, the data that appear to support the difference model might in fact be indirectly supporting the deficit model.

#### STRUCTURAL OBSTACLES FOR WOMEN IN SCIENCE

Academic women in science face structural career obstacles that men often escape: workplace inequities, restrictions in mobility, career interruptions, discrimination in hiring/promotion/tenure, lack of formal and informal support early on, and isolation from the collegial network.

Miller-Loessi and Henderson (1997) found academic women are disproportionately placed in lower-rank positions at universities. In 1993-94, according to the American Association of University Professors, 58 per cent of all academics in the non-tenure positions of full time lecturer and instructor were women. Furthermore, women represented only 43 per cent of assistant professors, 30 per cent of associate professors, and 15 per cent of full professors. Also, within each rank listed, women earned, on average, lower salaries than men.

Several studies have found that marriage has a positive effect on publication productivity for women scientists (Cole and Zuckerman, 1984; Astin and Davis, 1985; Clark and Corcoran, 1986; Davis and Astin, 1987; 1990; Sonnert, 1995a; Sonnert, 1995b; Astin and Milem, 1997). One of the most prevalent negative effects of marriage for academic scientists is lack of geographic mobility; this restriction is most prevalent for female scientists. As Sonnert and others have shown, marriage is generally beneficial for both male and female scientists. However, more academic women scientists are married to fellow academics and therefore face the 'trailing spouse' problem.

Sonnert found that 62 per cent of the female scientists in his study had a spouse with a doctorate (compared with only 19 per cent of the male scientists).

Many researchers who study the career patterns of women scientists, have found support for a phenomenon that is typically referred to as 'the leaky pipeline'. Overall, women scientists accrue fewer advantages and more disadvantages than men scientists as they travel down the science pipeline. The accumulation of negative experiences and gender-specific disadvantages along a scientific career path often explains the reason why more women than men leave science. In short, the scientific pipeline for women is often referred to as 'the leaky pipeline' because women are more likely than men to leave science for both the short term (career interruptions) and the long term (career change).

Sonnert (1995a) found that women are more likely than men to interrupt their graduate studies because of familial obligations. In addition, these interruptions were associated with a higher likelihood of eventually leaving science altogether. By contrast Cole and Zuckerman (1991) found that eminent women scientists who were married published more (3.0 compared to 2.2 articles per year) than single eminent scientists. Within the group of married eminent women scientists interviewed, the women with children published slightly less (2.9 compared to 3.3 articles per year) than the married childless women. With respect to motherhood, Cole and Zuckerman concluded that having children does have a slight negative effect on the publication rates of women scientists; however, this effect is quite small and married women scientists with children still publish more than the single women in the sample.

Several researchers have explored the relationship between gender and academic career status attainment (Reskin, 1977; Cole, 1979; Astin and Bayer, 1979; Cole and Zuckerman, 1984). Even though formal gender discrimination against academic women in science is still an operative structural barrier, many current studies suggest that most women scientists are discriminated against through a series of small events that contribute to a significant cumulative disadvantage for career advancement within academe (Fox, 1991). For example, career setbacks early on in a woman's career (for example, lack of pre-graduation publications with advisor) could lead to additional setbacks later that were caused by the previous acts of discrimination (for example, difficulty getting a competitive tenure-track position because of a weak publication record).

Several studies have demonstrated that a woman's academic work does not receive equal recognition to a man's academic work when it comes to academic rewards like salary increases and promotions (Ferber, Loeb and Lowry, 1978; Astin and Bayer, 1979; Cole, 1979). In 1984, Cole and

Zuckerman proposed the concept of 'differential reinforcement' and argued that women scientists publish less than their male counterparts because of more limited recognition and less use of their research. If research performed by women scientists is actually utilized and recognized less than research by men scientists, this serves as yet another support for the theory of cumulative career disadvantages for academic women scientists. Tuckman (1976) found that the correlation between publication and salary levels is much higher for men than it is for women. In 1979, Cole found that academic women lag men in rank even when controlling for both quality of publications and quantity of publications.

Ahern and Scott (1981) compared pairs of men and women that were matched on four characteristics: (1) year in which PhD was received, (2) field of PhD, (3) institution from which doctorate was awarded, and (4) race. They found that the men in the sample were about 50 per cent more likely to have been promoted to the rank of full professor within 10 to 19 years after receiving their doctorate. When Astin and Scott controlled for marital status, parenthood, and teaching/research proportions among the younger participants, they found that women also lagged behind men in promotion from assistant professor to associate professor.

One would expect that a lack of both formal and informal support before doctoral graduation would affect the advancement of a graduate student after graduation (and perhaps throughout their whole career). Long and McGinnis (1985) found that one of the most beneficial acts that an advisor can provide for his/her doctoral students is to collaborate in publishing before the student graduates. They additionally found that collaboration with a mentor could affect both job placement after the student graduates and future levels of productivity.

Even though studies show that men and women graduate students are almost equally likely to receive financial support during graduate school (Centra, 1974; National Research Council, 1983), women report more isolation from fellow graduate students, faculty members, and research advisors throughout their graduate training than men do (Centra, 1974; Holmstrom and Holmstrom, 1974; Kjerulff and Blood, 1973).

Many researchers argue for a broad concept of science as social. Mary Frank Fox (1991) applies this concept to the sociology of gender when she argues that we must look at social and organizational processes before we can understand gender differences in publication rate and rank achievement within academe (Fox, 1991). Fox contends that we must consider how collegial interaction, work climate, collaborative opportunities, and institutional settings might affect the productivity rates of men and women in academic settings (Fox, 1985; 1991). Within academia, major decisions about

rank, status, and position are typically decided in quite informal settings within the collegial network (Fox, 1991).

Sonnert (1995a) found that women scientists often felt exempt from many informal social events such as attending weekend parties or going out for drinks. This was particularly true for women who had children and were not married to fellow scientists. These women were more likely to have restrictive schedules that did not allow them to do things outside of the regular work week. Sonnert explained that it was a disadvantage for women to be absent from these events because more than half of his interviewees believed that social interactions with peers had an effect on the path of a scientist's career. Some of the women in Sonnert's study said that they felt that important career information was exchanged at many of these informal meetings and that, therefore, they were excluded from some of the departmental decision-making processes.

Studies on collaboration have shown that even though women scientists are generally just as likely to collaborate as men scientists, they have significantly fewer numbers of different collaborators (Cole and Zuckerman, 1984; Cameron, 1978). This could help explain why women scientists (as a group) publish less than men scientists. Studies on collaboration are inherently linked to the issue of informal social networks and women's isolation from the collegial network.

Presser (1980) and Gordon (1980) determined that single-authored papers are more likely to be rejected than co-authored papers. One explanation for this could be that single-authored papers are less likely to be the result of funded research than co-authored papers (Heffner, 1979). However, this finding could provide one explanation for why women scientists tend to publish less than men scientists. If women have fewer collaborators (and therefore fewer outlets for co-authored pieces), then it is possible that they produce more single-authored pieces than their male counterparts and these papers are less likely to be accepted for publication. In this way, exclusion from informal collegial networks could serve as one more disadvantage that adds to the cumulative effect of a lower publication rate for women scientists.

#### IMPLICATIONS FOR OUR STUDY

Our study uses previous findings more as a source of framing and interpretation than hypothesis testing. While many previous studies have focused on productivity as measured by publications, our concern is with career progression, likelihood of receiving a grant and impacts of grants on career progression. We were unable to identify studies that used relatively large samples and longitudinal data to examine grants' effects on career

progression. We feel that our results are not generalizable to all university scientists. There is no reason to believe that persons working in interdisciplinary, externally funded science and engineering centers would be representative. However, given the importance of this group and, generally, the increasing focus on centers, the findings are important in their own right.

#### ADVANTAGES AND DISADVANTAGES OF CV-BASED DATA

For the analysis that is presented in this chapter, we used data that were coded from the CVs of academic scientists and engineers. Data are from university-based interdisciplinary science centers funded by the National Science Foundation and the Department of Energy (for further details on the sample see Dietz et al., 2000). The collection of CVs was limited to the fields of biotechnology, biochemistry, bioengineering, and microelectronics. The data examined here are from 1061 CVs, including those of 136 female scientists. All of the scientists in this database have received a doctoral degree at some point during their career. No students are included in the data, but postdoctoral researchers are included.

One purpose of this chapter is to illustrate the possibilities for working with CV-based data and, thus, we consider here some of the peculiarities of method (see Dietz et al., 2000, for a more extended treatment). One striking aspect of the use of CVs is the abundance of information they provide. This is a blessing and a curse. When one considers that some CVs include hundreds of publications and conference papers, many with multiple authors, the costs of labor become apparent. The options are few. Capturing and coding all the information provided in CVs is extremely cost and labor intensive. The use of CVs almost necessarily requires strict limits on the data to be captured. Absent prodigious data entry resources, the only option is to forgo much data or to categorize data at a relatively high level of abstraction (for example, simplify authorship order). Unfortunately, however, too high a level of data aggregation is incongruent with the theoretical complexities of the knowledge value model.

Successful use of CVs requires an ability to optimize time, data capture, and labor. The hazards in CV use include insufficient culling and poorly predicted labor requirements. With anything less than complete data capture, the specific decisions about the operationalization of CV data are vital. Even after whole sections of data are dismissed (for example, we chose to ignore conference papers, courses taught, internal working papers), one still must grapple with measuring the remainder. Is it important, for example, to capture not only article publications but also author numbers and author order? How does one represent data in more economical indices and, more to the point,

how does one know which indices are most useful without sufficient original data to employ in indices? Are data best represented in arrays, across time, or in cross-sectional detail? If the CV database is to serve as a general resource for multiple research objectives, making decisions is made more difficult because there are only research themes and interests, not hypotheses, available for guidance.

An interesting problem is in identifying long versus short CV versions. A great many CVs get condensed or truncated (for example, 'most recent publications') and the information that may seem important in an early career (for example, all conference presentations) may be unimportant to the scientists later and may disappear entirely from the CV. The opposite problem is CV 'embellishment' where every career detail gets recorded with seemingly equal weight. We are certainly able to delete extraneous information, but information not included is information lost. Aside from the database problems such variation can cause, there are significant validity issues and issues regarding coding accuracy, coding labor and duration, and coding fatigue. And, despite explicitly asking for long-version CVs, about one in five of the CVs submitted for this study, were short versions.<sup>1</sup>

By almost any standard, the coding of more than a few CVs is a daunting task. Coding error rates from relatively tractable survey data range from about 5 to 10 per cent (Fowler, 1988). What about more difficult, less obvious CV data? While coding errors can at least be determined with some ease, it is not clear even which standard is best for coding reliability. Moreover, good measures of intercoder reliability require a good number of coders, again accelerating costs. Most important of all, however, is coding validity. Except for the most straightforward issues, CV coding is almost always sure to cause problems for any but the best-trained eye. Explaining to a coder how to deal with visiting professors working at (apparently) three different places, in two sites, with three ambiguous titles requires time, patience, and imagination. For example, the difference between a postdoc and a fellow may be vital in some instances, but not others. And how does one determine if a proceedings publication is consequential when working in a number of very different fields?

Developing an adequate codebook for a CV database is unusually important. Since the number records included is generally considerable and since the data are sensitive to the many procedural, coding, scaling and recoding decisions made along the way, a precise and detailed codebook is key.

If one masters the coding, labor, operationalization and truncation problems of working a CV database, the results can prove quite rewarding. In the first place, longitudinal databases are all too rare in the social sciences and CVs, when treated as career trajectory data, are necessarily longitudinal.

Second, it is in principle easy to merge secondary data from other sources (for example, ratings of programs, citation and patent data), although this too can be laborious. Finally, collecting CVs is generally a relatively unobtrusive source of data. It is typically easy enough for a scientist to send a CV as an email attachment; much less time is required than for, say, an interview, a questionnaire, or a log of activity. Much of the burden of the research is shifted to the researcher, not an entirely bad outcome when one is working with a highly studied group of unusually busy individuals.

#### CODING METHODOLOGY

To develop a preliminary coding protocol, we reviewed a subset of the CVs from each of the four respondent groups to identify problems and potential solutions. Over 30 potentially useful variable 'sets' were identified. However, many of these variable sets included multiple (that is, up to 10) degrees received, multiple (that is, up to 600) publications, multiple (that is, up to 50) patents, and so forth. The number of variables for each respondent depends, unlike a questionnaire, on the length of the CV. Junior researchers could have as few as 25 variables per CV; seasoned veterans could have as many as 2000. Several practice coding exercises were conducted to obtain information on intercoder reliability, to improve the coding protocol and process, and to minimize coding time.

To test intercoder reliability, we examined coding decisions of five coders on a subset of 37 variables from two sets of 10 CVs. Various measures of intercoder reliability have been proposed (see Scott, 1955; Craig, 1981; Funkhauser and Parker, 1968; Fleiss, 1971; Landis and Koch, 1977; Crittenden and Hill, 1971; Montgomery and Crittenden, 1977), but for our purposes we found Crittenden and Hill's measure of intercoder reliability (Rs) (Crittenden and Hill, 1971) the most useful and relevant. Overall, the average reliability coefficient value of 0.766 on the first round of coding shows that we would be wise to heed the advice to further refine the instrument and coding scheme. While there is no widely accepted 'threshold level' of intercoder reliability, for this particular coefficient anything below 0.850 should probably be considered problematic and anything below 0.600, outright unacceptable. Only 16 out of 37 items satisfied the 0.850 requirement. However, 7 out of 37 items fell below 0.600. The principle coding problems stemmed from the limited standardization in CV formats (possible international effects compound this problem), missing information, and coder error or the misinterpretation of data.

A closer inspection of the errors, however, demonstrated that many of them were due to coders coding information out of order (for example, coding

the second publication in the third publication variable spot) which compounded to ensure future errors. In addition, coders had significant problems with the original codebook which was revised and resubmitted to a second test (which we label coding trial 2 in Tables 15.1 and 15.2) using the same coders but new CVs. We expected there would be improvements due to the enhanced codebook as well as learning effects, and we were correct. Tables 15.1 and 15.2 show that the mean intercoder reliability rate increased to 0.805.

Table 15.1 Intercoder reliability and time of coding for 10 CVs

Curriculum vitae	Rs(i) for coding trial 1	Coding time (in minutes) trial 1	Rs(i) for coding trial 2 <sup>†</sup>	Coding time (in minutes) trial 2
1	.897	23.0	.938	18.0
2	.797	31.0	.765	21.0
3	.651	27.8	.881	18.4
4	.839	23.4	.709	14.4
5	.868	24.0	.792	15.6
6	.608	15.0	.830	16.0
7	.756	30.4	.830	13.8
8	.800	19.4	.630	21.8
9	.728	19.8	.832	18.0
10	.714	22.2	.849	10.0
Mean	.766	23.6	.805	16.7
Std. Dev	.090	5.02	.088	3.51

Note: Rs(i) stands for resume intercoder reliability.

† Coding trial 2 used the same coders with different CVs and an improved coding protocol.

There were 15 items that scored above the 0.850 level and three that scored below 0.600. While, in general, we felt that these intercoder reliability rates were still unacceptably low, we recognize that the complexity of the coding task at hand is such that we should expect rates below that achieved in more typical questionnaire coding. But to address the problem directly, we put in place a more elaborate coder training program and worked more closely with coders during the actual coding operations than we originally expected. We also relied more extensively on post hoc data cleaning than may be typical.

Table 15.2 Intercoder reliability for coding 37 items

Item #	Rs(i) coding trial 1	Rs(I) coding trial 2†	Item name
1	.933	.682	CV version is full or partial
2	.933	1.000	Sex of respondent
3	.960	1.000	Year of birth
4	.920	.800	National origin
5	.920	.780	Citizenship
6	.880	1.000	Degree type of first degree
7	.690	.840	Degree field of first degree
8	.860	.880	Degree type of second degree
9	.880	.670	Degree field of second degree
10	.960	.960	Degree type of third degree
11	.810	.800	Degree field of third degree
12	1.000	1.000	Degree type of fourth degree
13	1.000	1.000	Degree field of fourth degree
14	1.000	1.000	Degree type of fifth degree
15	1.000	1.000	Degree field of fifth degree
16	.560	.570	Job title of first job
17	.490	.490	Job title of second job
18	.610	.770	Job title of third job
19	.680	.680	Job title of fourth job
20	.600	.410	Job title of fifth job
21	.740	1.000	Publication type of most recent
22	.790	.960	Publication type of second most
23	.630	.860	Publication type of third most
24	.550	.860	Publication type of fourth most
25	.880	.760	Publication type of fifth most
26	.620	.780	Dollar amount of first grant or
27	.570	.520	Funding source of first grant or
28	.630	.760	Dollar amount of second grant or
29	.580	.680	Funding source of second grant or
30	.690	.760	Dollar amount of third grant or
31	.560	.710	Funding source of third grant or

32	.690	.760	Dollar amount of fourth grant or
33	.660	.620	Funding source of fourth grant or
34	.660	.780	Dollar amount of fifth grant or
35	.580	.690	Funding source of fifth grant or
36	.893	.960	Year of first patent
37	.933	1.000	Was first patent licensed or sold?
Mean	.766	.805	
Std. Dev.	.164	.163	

Notes: Rs(i) stands for item intercoder reliability.

†Coding trial 2 used the same coders with different CVs and an improved coding protocol.

Interestingly, we found in both experiments that coding time was unrelated to error rate suggesting that our reliability problems were due either to the complexity of the CVs, the complexity of our coding scheme, the motor skills and knowledge of our coders, or all three.

In Table 15.3, we present the descriptive characteristics of our sample, including male and female differences (two-tailed t-test of significance). As has been found in many other studies of scientists, there are frequently significant differences in the characteristics of men and women. Women are significantly less likely to have held a postdoctoral position, and are also less likely to have any experience outside of academe. About two-thirds of men and women publish before completing their PhD. Women in this sample completed their doctoral training on average six years later than the men. Looking at the PhD cohort variables, note that men are disproportionately represented in the 1950-70 cohorts, a likely reflection of structural barriers to women entering competitive scientific careers. Among scientists completing their PhD in the 1980s, however, each sex is equally represented. By contrast, the PhD cohort of the 1990s is disproportionately female in this study. This unanticipated result warrants further qualitative attention.

The professional careers of men and women are dissimilar in some respects, especially in the upper ranks. Men and women are equally likely to have ever held an assistant professor position, and they take on average 10 years to be promoted to full professor from the beginning of the assistant professorship. They are also equally likely to be pursuing a traditional career trajectory that progress from assistant, to associate, to full professor without breaks or out-of-order events. By contrast, men are significantly more likely to have attained the rank of associate and full professor.

Table 15.3 Professional characteristics of a sample of male and female scientists

	All	Men	Women	Significance
N	1061	925	136	
Percentage		87	13	
<b>Training experiences</b>				
Doctoral year	1983	1982	1988	***
Postdoctoral study	0.3	0.40	0.29	**
Any non-academic	0.55	0.57	0.40	***
Publish before PhD	0.62	0.61	0.68	ns
<b>PhD Cohort</b>				
1950s	0.03	0.03	0	
1960s	0.13	0.14	0.06	**
1970s	0.2	0.21	0.13	**
1980s	0.3	0.3	0.27	ns
1990s	0.35	0.32	0.54	***
<b>Professional career</b>				
Ever assistant professor	0.63	0.62	0.69	ns
Ever associate professor	0.55	0.56	0.46	*
Ever full professor	0.45	0.48	0.26	***
Years PhD to full professor	12	12	10	***
Years assistant to full professor	10	10	9	ns
Traditional Trajectory	0.62	0.61	0.69	ns
Total number of publications	65	68	38	***
Annual rate of publications	4	3	4	**
Ever award grant	0.39	0.39	0.36	ns

Notes: \*\*\* $p < .0001$ ; \*\* $p < .001$ ; \* $p < .05$  two-tailed tests; ns = not significant.

This dynamic can be seen quite dramatically in Figure 15.1, which shows the survival curves of men and women in the data. The bottom line representing men drops earlier and more rapidly, indicating that men are experiencing entry into the rank of full professor at a faster rate than women. There are, of course, many dynamics that could explain this. The most important is the length of the career. Since fulfilling time in rank is a necessary criterion for promotion, the women – who tend to be younger than their male colleagues – often have not had the opportunity to come up for tenure or promotion. We explore this dynamic in more detail in a subsequent section.

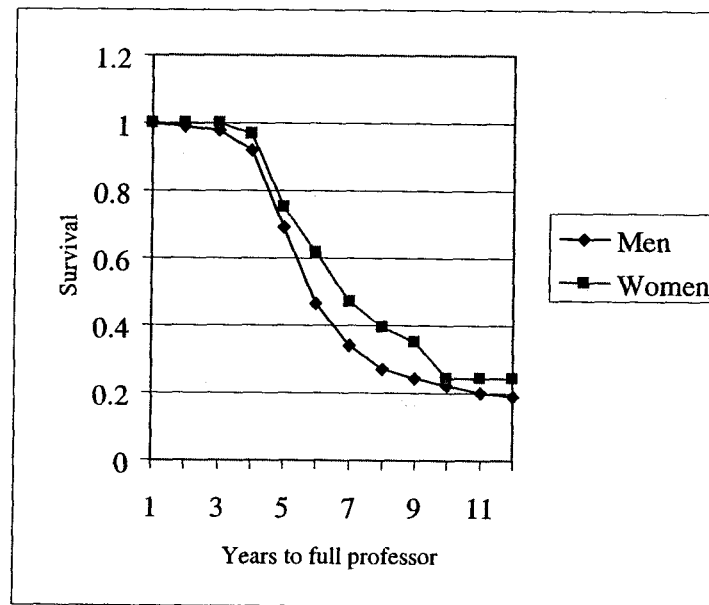


Figure 15.1 Time from PhD to full professor

In terms of productivity, men tend to publish more manuscripts, averaging 68 publications to women's 38. Men have also been awarded almost twice as many grants. However, men are just as likely to have been awarded grants as women, and neither group is particularly successful in winning grants before completion of the doctorate. Just as with the discussion of promotion to full professor, one must take care reading too much into bivariate relationships that do not control for time spent in the career, as we shall do in the next section.

#### SIZE OF GRANT AWARDS

One of the issues we are particularly interested in is the role that research grant awards play in scientists' careers. Figure 15.2 illustrates the differential career trajectories of scientists with and without grants. Scientists who have been awarded at least one research grant (bottom line) are significantly more likely to be promoted to full professor than their colleagues who do not have grant awards. Although men and women do not differ in the proportions who

are awarded grants, there are significant qualitative difference evident at the time of the first grant, and across the academic lifecourse.

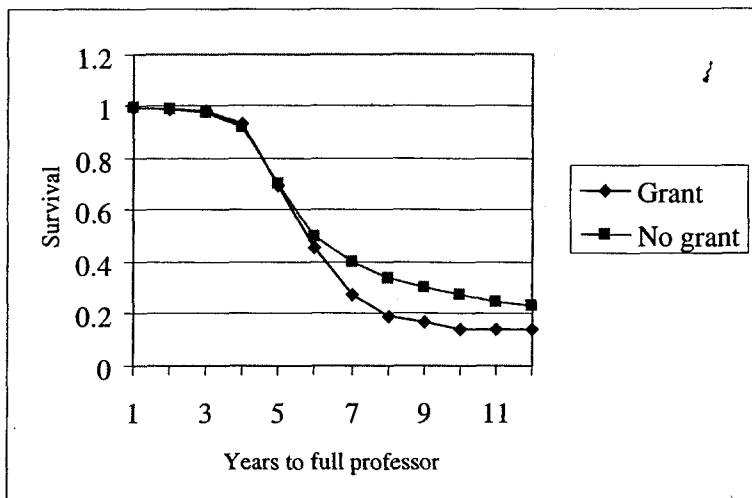


Figure 15.2 Grants and time to full professor

Table 15.4 Grant histories of award-winning scientists

	All	Men	Women	Sig- nifi- cance
N	412	363	49	
Percentage		88	12	
Grant before PhD	0.03	0.02	0.05	ns
Years to first grant	5	4	5	ns
Mean first grant	\$397997	\$435221	\$119927	***
Median first grant	\$65000	\$69000	\$44000	n/a
Number of grants	7	7	4	***
Average all grants	\$484274	\$497356	\$387528	ns
Grant per year	\$435612	\$464936	\$207162	***

Notes: \*\*\* $p < .0001$ ; \*\* $p < .01$ ; \* $p < .05$  two-tailed tests; ns = not significant.

The average amount of the first grant awards of men is \$435 221, significantly higher than women's average of \$119 927 (Table 15.4). This disparity is also evident in the median grant award, which is less responsive to

extreme cases. The median first grant award to men is \$69 000 in contrast to women's median first grant of \$44 000. There are no differences in the precocity of new investigators – men and women are equally unlikely to be awarded a grant before completion of the PhD, and take on average 5 years to be awarded the first grant. This latter finding is interesting because it suggests that the initial years in an assistant professorship are often years of resource scarcity for new academics. It also suggests that grant activity is a more important predictor later in the career as professors come up for subsequent promotions. Over an academic lifetime, men are awarded almost twice as many grants as women, but note that all of the grant-winning scientists are high achievers. Sixty-seven per cent of female grantees ( $n = 49$ ), and 80 per cent of male grantees ( $n = 363$ ) have been awarded more than five grants. Standardizing the total grant activity by each scientist's academic longevity reveals great differences between men and women. Male grantees enjoy an average annual grant support of \$464 936, while women are supported, on average, at \$207 162 per year.

Given the different gender and grant dynamics evident in univariate and bivariate analysis, we are interested in examining the extent to which gender and research grants explain important career transitions in the life of a scientist. Why do women receive lesser amounts than men and what impact does that have on academic performance? We do not have sufficient data to provide a strong explanation, but we can consider some hypotheses. Women may receive lesser amounts as a direct result of discrimination or simply because they are not as aggressive in asking for large amounts of resources. Both the 'difference' and 'deficit' models may be in play here. But there are also many artifactual possibilities that must be ruled out. For example, the percentage of women in physics is especially low compared to men and physics receives large grants, in part because of costs of equipment. Similarly, women are more likely to go into chemistry, a relatively low resources field. Differences could possibly be based on cohort effects. Many agencies have curtailed the amount of grants in order to spread them more widely. Since those trends have developed recently and since there are more women in the sample who are still early career, it is conceivable that structural changes in the amount of grants would differently affect women.

#### IMPACTS OF GRANTS: TENURE AND PROMOTION

We can obtain a somewhat fuller understanding of the relationship between receiving a grant and gender by controlling for time since PhD (and time since PhD squared, a non-linear transformation). One might suspect, given the fact that women in the sample have different median career spans, that the

comparative earlier vintage of the men in the sample might affect the relation to obtaining a grant.

Does time since PhD have an impact mediating the effect of gender and grants on time to promotion to full professor? Table 15.5 reports a Cox proportional hazard model, which is ideal for this type of analysis. Also known as event history analysis, its dependent variable is the length of time to experiencing an event. Its strength over cross-sectional regression approaches is the ability to take into account censoring – those scientists who have not yet experienced a promotion to full professor (Allison 1984; 1995). In the model we present here, we control for the professional age of the scientist because promotion to full is very much a function of time. The inclusion of time squared accommodates the first rising, and then decreasing chances of being promoted to a full professor in one's career. We include three theoretically relevant covariates: sex, time to first grant, and the annual publication rate. If deficit or difference theories of scientific gender dynamics are true, being male should be differentially advantageous. Having obtained grants should increase the likelihood of being promoted, as should the annual publication rate of the scientist.

Table 15.5 *Impact of grants, publications, and gender on time to full professor*

	Beta	Sig	Odds ratio
Time since PhD	0.21	0.0001	1.24
Time squared	-0.003	0.001	0.99
Male	0.1	0.71	1.11
Time to grant	-0.05	0.0001	0.95
Publication rate	0.1	0.0001	1.1

The best way to describe the results of these models is to exponentiate Beta so as to convert it to more intuitively comprehensible odds ratios, shown in the last column. As expected, each additional year following the doctorate results in a 24 per cent increase in the odds of being tenured, net of other covariates. Contrary to the difference or deficit hypotheses, there seems to be no independent effect from gender in this sample: men and women are equally likely to be promoted to full professor. Those with grants are more likely to be tenured. In this specification, the odds of being promoted decline 5 per cent for each additional year without a research grant award. Each additional annual publication results in a 10 per cent increase in the odds of promotion.

## PRELIMINARY ASSESSMENT

Our chief conundrum is that grants affect tenure and promotion, and women are no more or less likely than men to receive tenure or be promoted. One possible explanation that we do not at present have the ability to test, is that there may be an interaction effect between the amount of the grant and simply having a grant. Perhaps male scientists benefit in tenure and promotion from having larger grants, women benefit more than men just because they have grants, and the effects wash one another out resulting in roughly equivalent rates of tenure and promotion. But this is just one among many possibilities, including field effects, results from the relatively small number of women in the sample, peculiarities of a sample from interdisciplinary science centers, and possible cohort-related artifacts not picked up by the simple measure of time since PhD. With more data and, particularly, a more representative database that can be used to compare our distinctive database, it should be possible to employ CVs to sort out these complex relationships.

## IMPLICATIONS OF FINDINGS FOR FUTURE RESEARCH

The results that we have presented seem to us to have interesting and complex implications for public policy regarding gender differences in science. While much of the current literature on women in science does not indicate that women face blatant structural obstacles during academic career paths, they do still face inconspicuous discrimination that makes them lag behind their male colleagues increasingly as they progress through their careers.

It seems apparent, in this study as well as others, that women scientists who complete a doctoral degree and begin a career in academe are often the 'cream of the crop'. They have survived many difficulties along the way and have thrived. Regardless of how these women strive to make up lost time and catch up with their male colleagues (for example, our findings about funding discrepancies between men and women), they have a harder road ahead of them.

We have reached a stage in public policy and gender discrimination when we no longer need to worry about a woman being told that she cannot be an assistant professor because she is not of the 'right' sex. The courts and the specific woman could take care of this matter in short order. Rather, we do have to focus our public policies in the future regarding gender on the small discrepancies and the small, nearly invisible, acts of discrimination that place women behind men as they progress through their careers.

We no longer need to investigate whether women are becoming assistant professors with the same likelihood as men. Rather, we need to focus on the

amount of funding that women receive *after* they are professors, the amount of collaboration that women engage in *after* they are professors, and whether women are getting the resources that they need to jump the tenure fence and thrive as senior scientists.

Our public policies, in the future, need to target issues like these for balancing the discrepancies between men and women and giving women the chance to make up for the lag. In addition, career interruptions are obviously a more serious problem for women scientists than men scientists. Maybe the time has come to consider not what is best for science (that is, how can we get women to publish more) but rather what is best for women scientists (that is, how can we make science fit with what is best for women).

#### IMPLICATIONS OF CV ANALYSIS FOR RESEARCH EVALUATION

Despite demonstrated difficulties of using the CV as a tool for research evaluation, we feel our study at least shows the promise of this technique. In the first place, the CV is for scientists a peculiar document for their research history, a dynamic document that the scientist changes regularly to reflect career changes. Second, there is some degree of standardization in the CV. One can expect reflections of major career changes and most significant outputs and activities, including grants, publications and patents.

We feel we have demonstrated the most important limitations of the CV as a data source, including coding time and effort, variety in the CV, the increasing use of tailored and truncated CVs. One point relevant to cross-national evaluation is the tendency for different CV norms even within a profession, science, that has strong universalistic tendencies. In comparing our data base to a CV database gathered by our French research colleagues at University of Grenoble, we find very different norms among the French regarding listing of spouses, family data and other personal information (French CVs usually provide this information, US CVs do not). For persons interested in evaluating career trajectories such cross-cultural difference are important.

Perhaps the greatest utility of CVs is for multi-method evaluation. Using the CV as a starting point, it is possible to use citation and patent analysis for amplification of career data and it is possible to use questionnaire-based data to get at the motivations for career changes and the reasoning behind collaboration choices.

In sum, the uses of CVs for research evaluation are just beginning to appear and, quite possibly, this data source will become more and more important as new uses emerge and as connections to more traditional evaluation data and approaches become apparent.

#### NOTE

1. Interestingly, the availability of CVs on the web has been helpful and hurtful to those interested in the CV as data. The popularity of the web has meant that a great many more CVs are accessible, but the institutionalization of websites has led to a stylistic conformance of CVs, which is not itself a problem, and, typically, significant abridgment, which can be a great problem. If the CV on the web is typically an institutional rather than individual marketing resource, the rational marketing approach is succinct information about more people, rather than detailed information about particular people.

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