Survival Analysis of Faculty Retention in Science and Engineering by Gender

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Supporting Online Material
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Survival Analysis of Faculty Retention in Science and Engineering by Gender

Deborah Kaminski[1]* and Cheryl Geisler[2]

Individual assistant professors (a total of 2966 faculty) hired in science and engineering since 1990 at 14 United States universities were tracked from time of hire to time of departure by using publicly available catalogs and bulletins. Results of survival analysis showed that the chance that any given faculty member will be retained over time is less than 50%; the median time to departure is 10.9 years. Of all those who enter as assistant professors, 64.2% were promoted to associate professor at the same institution. Overall, men and women are retained and promoted at the same rate. In mathematics, however, faculty leave significantly earlier than other disciplines, and women leave significantly sooner than men, 4.45 years compared with 7.33 years.

U.S. universities are concerned about faculty retention in science and engineering (*1*–*4*). When a faculty member leaves prematurely, they suffer disruptions in teaching and mentoring as well as significant economic losses (*1*). Start-up costs in engineering and natural sciences can range from $110,000 to nearly $1.5 million (*3*), and it may take up to 10 years to recoup this investment (*4*).

Retention rates for faculty in the United States have been consistent. From 1971 through 1989, faculty members were retained at rates of 90 to 92% for associate and full professors and 84 to 86% for assistant professors (*5*). In 1996–1997 and 2001–2002, the retention rates for associate professors were again in the range of 90 to 92% (*6*).

Problems with the retention of women in science and engineering in the United States have been well documented. Like a leaky pipeline, each career stage in engineering and the natural sciences shows the retention of women lower than the stage before it (*3*, *7*). In particular, although women are increasingly represented among those with earned doctorates, they lag behind in representation in the academic faculties (*8*).

The problem appears to lie in differential application rates. Once women apply for or are in consideration for a career move, they are equally likely to succeed, but they are often not in the pool (*3*, *9*–*11*). Men have been found to be significantly more likely to receive tenure or move to positions outside of academia, whereas women are significantly more likely to be unemployed or to exit the tenure track for adjunct positions (*3*). Women with Ph.D.s in science, technology, engineering, and mathematics (STEM) disciplines have also been found to be less likely than men to be employed full time, although equally likely to succeed if they apply (*11*).

Women have also been shown to have greater intentions to leave the STEM disciplines (*12*), although not academia as a whole (*13*), and to leave for different reasons. Whereas salary is the number one reason for men, women cite more interpersonal and family reasons (*14*, *15*). Delays in tenure resulting in lower salaries could account for women leaving before tenure (*16*), but department climate is a primary reason why women are less satisfied and more likely to quit (*4*).

Significant disciplinary variations exist in the retention of women in science and engineering. In the disciplines included in this study, the rate of growth in earned doctorates, the level of representation in the pool of Ph.D.s, and representation in the ranks of assistant professors all showed marked disciplinary differences between men and women (*8*). At research I universities in six of the nine fields included in this study, the mean percentage of those who applied, were interviewed for, and were made offers to was closer to the percentage of women in the relevant doctoral pool for electrical engineering, mathematics, and physics, where their representation was lowest, than in chemistry and biology, where their representation in the pool was highest (*11*).

Women's representation among earned doctorates is particularly high in the biological sciences (*8*). Between 1972 and 1991, representations of women in all levels of academics was highest for life sciences and lowest for engineering, with physical science in between (*9*). The probability of having a tenure-track position 10 years after Ph.D. is significantly smaller for women in the life sciences but about the same for those in physical and engineering sciences (*9*). In the biological and life sciences, where women are most heavily represented, they have an 8 to 9% less chance of getting a tenure-track job, getting tenure, or getting promoted to full professor (*9*). In terms of retention, one study reports that women and minority faculty have higher turnover intentions in the pure and applied life sciences as well as in the pure physical sciences, but not in the applied science areas that include the engineering fields (*1*).

In this study, we tracked 2966 science and engineering faculty from 14 universities from time of hire to the time they left the university. All data were obtained from publicly available

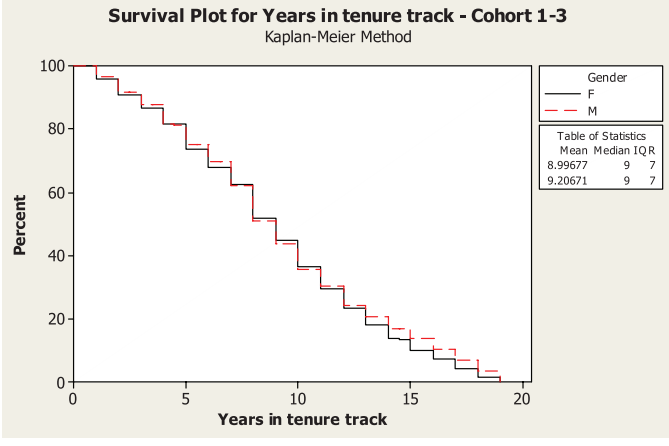

Fig. 1. Nonparametric survival curve for faculty who entered between 1990 and 2002 by gender. IQR, interquartile range.

[1]Department of Mechanical, Aerospace, and Nuclear Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180, USA. [2]Faculty of Communication, Art, and Technology, Simon Fraser University, Harbour Centre 7410, 515 West Hastings Street, Vancouver, BC V6B 5K3, Canada.

*To whom correspondence should be addressed. E-mail: kamind@rpi.edu

college catalogs and bulletins (*17*). We divided our sample into five cohorts, beginning with those who entered from 1990 to 1993 and ending with those entering from 2006 to 2009. The sample size and composition of each cohort can be found in table S1. The question of retention was examined by using the first three cohorts, who arrived between 1990 and 2002 (*18*), as specified in table S2.

Figure 1 shows the Kaplan-Meier survival curve for cohorts 1 to 3. Large declines appear at years 5, 8, and 10; there is no significant difference between men and women. The data are correlated in Fig. 2, which includes parametric survival curves, probability density functions, and hazard functions. A log normal distribution provided the best fit to data, with a correlation coefficient of 0.983. The probability density function shows that departure rates are higher in the first 10 years. In the first 3 years, departure rates are somewhat lower, whereas in the next 3 years, departure rates are high. The survival function shows a rather steeper decline in faculty at early times and a more moderate descent at later times. It is apparent that posttenure faculty leave at a lower rate than pretenure faculty. The hazard function tells a similar story. This is the rate of attrition at a given point in a faculty career, and it peaks at about 6 years. The differences between men and women are small.

Table 1 gives the median time to departure for cohorts 1 to 3 by gender. Half of all entering faculty have departed by 10.9 years. There is no statistically significant difference between men and women. The 95% confidence intervals (CIs) on the median for men and women are nearly coincident.

Another perspective on faculty retention is available by examining promotion rates. The percentage of faculty in the first two cohorts who were promoted to associate professor is given in table S3. For the full population of 1032 faculty, 64.2% ± 3.65% were promoted to associate professor. There is no significant variation by cohort or by gender. For the first cohort, the average number of years to promotion to full professor was 10.73 for men and 10.91 for women.

These results give a broad view of parity between men and women in the areas of retention and promotion, consistent with several other studies (*1*, *11*). Women on the whole are less satisfied than men (*15*, *19*), but this dissatisfaction does not manifest as increased rates of departure.

There was no significant change in retention patterns from 1990 to 2002. There has been a substantial increase in the percentage of women hired into STEM faculty positions since 1990, as shown in fig. S1. These two facts together imply an increased presence of women in STEM departments over the long run. Those who are hired tend to stay, and the number hired is increasing. The time constant for the change in department gender composition is, however, very long.

Although there are no significant differences in retention by gender for the entire population, there are some disciplinary variations. Table 2 lists the median time to exit for men and women by discipline. A log-rank and Wilcoxon test for significant difference between two survival curves (*20*) shows no differences except in the case of mathematics, where $P = 0.0522$ and 0.008, respectively. Because of the choice of weighting function, the log-rank test puts more emphasis on differences at long times, and the Wilcoxon puts more emphasis on differences at short times. A Cox proportional hazards model was used to detect differences among disciplines regardless of gender. Two disciplines were significantly different. In mechanical engineering, faculty leave later than those in other disciplines ($P = 0.0006$), but gender differences are not significant. In mathematics, by contrast, faculty leave earlier than those in other disciplines ($P < 0.0001$), and the difference between men and women is stark. The median for men is 7.33 years, and the median for women is 4.45 years.

The Kaplan-Meier survival curve for mathematics faculty is presented in Fig. 3. Women leave at a significantly greater rate than men, including a dramatic decline at 5 years. The data were correlated with a log normal function, as shown in fig. S2. There is little overlap in the 95% confidence intervals for the men and women, indicating statistically significant differences. The correlation coefficients of 0.967 and 0.975 are high. The probability density function, the survival function, and the hazard function for mathematics faculty are given in fig. S3. The probability density function shows that women are much more likely to leave very soon after hiring than are men. This results in a survival curve in which very few women persist to the 20-year mark.

Previous large-scale analyses of the retention of academic faculty in the United States have relied on aggregate data or surrogate variables to track year-to-year turnover in STEM disciplines. The large-scale analysis reported here, which tracked the retention of individual faculty across time, confirmed some of the earlier results but points to new areas of concern. Although the use of college catalogs and bulletins as a data source is time-intensive, previous work has made the case for the value of using publicly available sources to monitor institutional change (*21*).

An early study based on American Association of University Professors data (*5*) found average attrition rates of 0.15 for assistant professors and 0.08 for associate professors. The values for assistant professors are much higher than our hazard function values, indicating that retention of assistant professors may have improved since 1990. In a more recent study (*6*), the attrition rates for all associate professors averaged 0.077. From our data, the hazard function at 10 years (representative of associate professors) was 0.0709, and at 8.5 years it was 0.073, consistent with the two earlier studies.

Our work confirms the importance of the late pretenure period as a period of critical risk in the retention of faculty in STEM. Like earlier analyses, we find that posttenure faculty members are overall less likely to depart than pretenure faculty. Overall, the chances that any

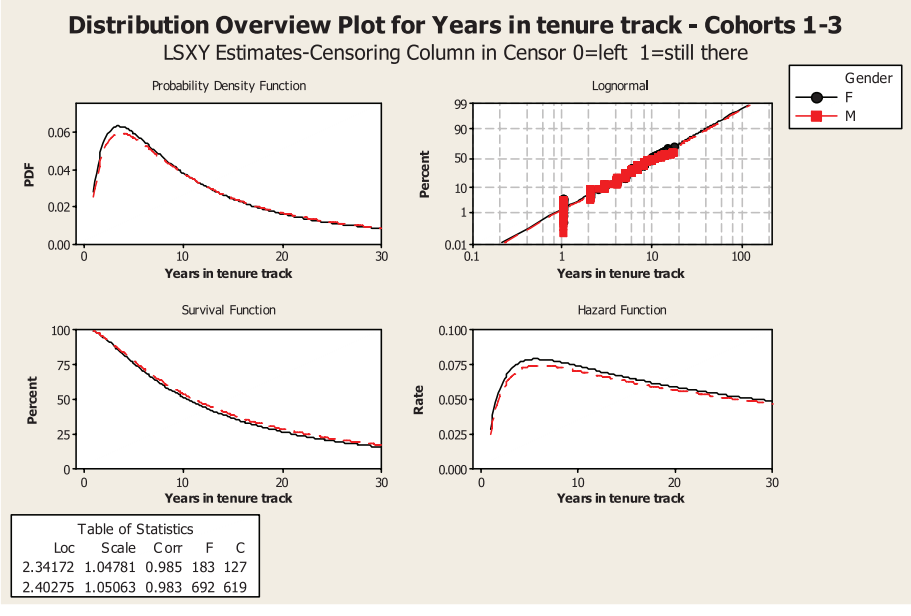

Fig. 2. Survival analysis of faculty who entered between 1990 and 2002 by gender. LSXY, least squares; F, number that left; C, number still remaining.

Table 1. Median times to exit the tenure track by gender, cohorts 1 to 3.

	Median time to exit, years	95% Normal CI	
		Lower	Upper
All	10.94	10.3	11.61
Men	11.05	10.34	11.81
Women	10.40	9.094	11.89

Table 2. Median times to exit the tenure track by gender and discipline for cohorts 1 to 3. CIs are for medians.

Discipline	Median years men	Lower 95% CI	Upper 95% CI	Median years women	Lower 95% CI	Upper 95% CI	*P* log rank test	*P* Wilcoxon test
Elec Eng	12.92	10.51	15.88	10.68	6.49	17.59	0.641	0.576
Physics	11.14	9.00	13.79	9.41	6.61	13.40	0.118	0.739
Mech Eng	16.19	12.80	20.46	10.41	7.10	15.24	0.109	0.153
Chemistry	12.46	10.07	15.41	10.53	7.57	14.64	0.980	0.847
Math	7.33	6.20	8.68	4.45	3.34	5.93	0.0522	0.0083
Comp Sci	9.32	7.64	11.39	10.25	6.87	15.28	0.5156	0.548
Civil Eng	8.68	7.01	10.76	10.74	7.48	15.43	0.970	0.262
Biology	11.96	9.30	15.37	16.36	9.20	29.10	0.0664	0.197
Chem Eng	11.64	9.00	15.05	9.78	5.95	16.08	0.393	0.687

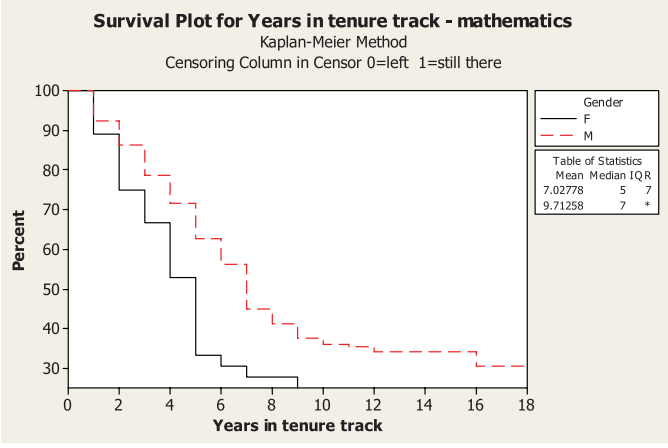

Fig. 3. Kaplan-Meier survival plot for mathematics faculty by gender, cohorts 1 to 3.

given faculty member will be retained over time is less than 50%; the median time to departure is 10.9 years. These retention data are rather stable over the 12-year period studied and may be resistant to change. Further work will need to be done to establish how much of this mobility results from the pull of better opportunities or the push of concern over tenure and how much results in a decision to leave the tenure track or the academic sector altogether.

Given the high economic and institutional costs of failures to retain, these low retention rates represent a substantial burden on institutions of higher education. Universities must be prepared to replace departing faculty and must plan for the high cost of start-up packages. If a university expects to grow its faculty, it has an even greater challenge. Simply staying the same size requires considerable hiring and mentoring, even without considering retirement.

The lack of gender effects in retention and promotion in our data is good news and confirms the patterns found in recent aggregate and indirect analyses (*1*, *3*). For all STEM disciplines considered together, the percentage of women hired is lower than men, but the retention rates are comparable. This indicates that, if the women are hired, they will likely persist and that recruitment is a more pressing issue than retention in achieving gender parity. However, the long span of faculty careers provides considerable inertia in the system. Marschke *et al*. (*22*) estimate that it would take about 40 years for a department to match the gender composition of the hiring pool because of the long length of faculty careers. Although our data do show an increase in percentage of women hired, the goal of 50% women may not be achieved until as late as 2050. Thus, if current trends continue, it may take 100 years before women are 50% of the faculty in STEM departments.

In our data, the discipline of mathematics stands out in two ways with respect to retention. First, it has the quickest departure rates in any discipline we studied. Second, there are statistically significant differences in the retention rates of men and women faculty. The median time to departure for men is 7.33 years, and for women it is 4.45 years. No other discipline shows gender effects at the 95% confidence level. Annual surveys of the discipline by the American Mathematical Society (*23*) track the recruitment of new doctoral recipients into academic mathematics but have not examined retention. Our data suggest that there are significant retention issues in the discipline deserving of further scrutiny.

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Supporting Online Material

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References
Data

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