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Unclogging the pipeline: advancement to full professor in academic STEM

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Unclogging the pipeline: advancement to full professor in academic STEM

Abstract

Purpose: Women remain underrepresented in academic STEM, especially at the highest ranks. While much attention has focused on early-career attrition, mid-career advancement is still largely understudied and undocumented. This paper analyzes gender differences in advancement to full professor within academic STEM at a mid-size public doctoral university in the western US, before and after the NSF-ADVANCE Program (2003-2007).

Methodology: Using faculty demographics and promotion data between 2008 and 2014, combined with faculty responses to two waves of a climate survey, the magnitude and longevity of the impact of ADVANCE on mid-career faculty advancement across gender is evaluated.

Findings: This study documents increased representation of women in all ranks within the STEM colleges, including that of full professor due to ADVANCE efforts. It also demonstrates the role of greater gender awareness and formalization of procedures in reducing the variability in the time as associate professor until promotion to full professor for all faculty, while also shrinking gender disparities in career attainment. As a result of the codification of the post-tenure review timeline towards promotion, more recently hired faculty are promoted more swiftly and consistently, irrespective of gender. Post-ADVANCE, both male and female faculty express greater understanding of and confidence in the promotion process and no longer see it as either a hurdle or source of gender inequality in upward career mobility.

Research limitations / Implications: While data were collected at a single university, demographics and career experiences by women mirror those at other research universities. This study shows that within a given institution-specific governance structure, long-lasting effects on faculty career trajectories can be achieved, by focusing efforts on creating greater transparency in expectations and necessary steps towards promotion, by reducing barriers to information flow, and by standardizing and codifying the promotion process.

Originality / Value: This study addresses mid-career dynamics and potential mechanisms that explain gender gaps in the promotion to full professor, a largely understudied aspect gender disparities in career attainment within STEM. It shows how institutional policy changes, intended to alleviate gender disparities, can benefit the career trajectories all faculty. Specifically, this study highlights the crucial role of codifying procedures and responsibilities in neutralizing subjectivity and inconsistencies in promotion outcomes due to varying departmental climates.

KEYWORDS: academia, STEM, promotion, gender inequality, policy, glass ceiling

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Introduction

Women have been entering academic STEM disciplines in increasing numbers since the 1980s (Burelli, 2008), yet they remain underrepresented at the senior ranks (Long and Fox, 1995; Valian, 1999; Mason *et al*, 2013). The National Science Foundation (NSF) ADVANCE program was initiated in 2001 with the specific goal of developing strategies to increase the representation and advancement of women in science and engineering disciplines at institutions of higher education in the United States. This paper analyzes gender differences in the rate of advancement to full professor within academic STEM at a mid-size public doctoral university in the western US, before and after participation in the NSF-ADVANCE Program (2003-2008). Using quantitative personnel data augmented with findings from two waves of a faculty climate survey, we investigate the magnitude and longevity of the impact of ADVANCE on mid-career faculty advancement across gender.

The pattern of declining representation of women up the academic STEM ladder is frequently compared to a “leaky pipeline” (Goulden *et al*, 2011). Some scholars attribute this progressive filtering of women scientists out of academic STEM solely to supply side factors, such as early self-selection into/out of science, individual career choices away from academia, lack of motivation, or lower success by women (Ceci and Williams, 2011; Ceci *et al*, 2014). An alternative metaphor, that of the “clogged pipeline”, might be more apt in describing the slower upward mobility of mid-career women. Due to structural barriers or institutional practices that create chilly working conditions or put women at an evaluative disadvantage, women’s advancement into these higher ranks is slowed or stalled, causing some to leave academia before reaching the full professor rank (Cech and Blair-Loy, 2010; Goulden *et al*, 2011). If significant gender gaps in mid-career advancement indeed exist, they are particularly puzzling since women scientists possess the human capital to be hired (Glass and Minotte, 2010; Williams and Ceci, 2015) and have successfully navigated the tenure process – the first critical gatekeeping event where significant faculty attrition takes place (Ceci *et al*, 2014).

Creating a balanced gender representation at all levels in STEM is important as it contributes to diversity of thinking and innovation in the sciences (Rosser, 2004). Women's advancement also maintains our scientific competitiveness worldwide by providing role models that entice young talent, especially underrepresented groups, to become part of the domestic, highly trained, scientific labor force (Rosser, 2004; Goulden *et al*, 2011). Within academia, career support for women faculty at all ranks also serves as an important mechanism for achieving gender equity in leadership and administrative positions as administrators are drawn from among tenure-track faculty ranks. This in turn engenders diversity in thinking and management style, instrumental in the recruitment and retention of a diverse faculty corps.

With a few exceptions (e.g., Sabatier *et al*, 2006; van den Brink and Benschop, 2011; Britton, 2017), the majority of studies on gender gaps in career attainment within academic STEM have focused on early-career, particularly personal challenges and institutional barriers to women faculty's success in attaining tenure (e.g., Goulden *et al*, 2011). There has been much less focus on mid-career dynamics and potential gender gaps in the promotion to full professor, especially for the US (Britton, 2010; 2017). The objective of this paper is to fill this knowledge gap by conducting a quantitative analysis of gender differences in the average time to promotion from associate to full professor at a single doctoral research university in the western U.S. before and after the implementation of the NSF-funded ADVANCE project. This university is representative of many institutions of higher education (IHE) with a strong research emphasis and where research productivity plays a key role in the promotion process. It was also one the early participants in the ADVANCE program, allowing us a longer retrospective timeframe to evaluate the program's impact. We were particularly interested to determine (i) the existence and size of the gender gap in career advancement prior to ADVANCE and (ii) whether there was a lasting post-ADVANCE impact on mid-career mobility for women. Our analysis provides valuable insights into which institutional practices are effective in mitigating gender differences in career attainment among STEM faculty. Our findings also identify practices that yield positive outcomes that are sustainable in the long term even in the more competitive environment associated with research universities, where gender

disparities at the highest ranks appear more acute (West and Curtis, 2006; Bakian and Sullivan, 2010; Britton, 2017). Thus, our findings can provide guidance to other universities that face similar challenges.

The underrepresentation of women across ranks in academic STEM is undisputed, but potential causes for this phenomenon or the best approach to normalize women's movement up the academic ladder are still the subject of considerable debate. One viewpoint, framed around the belief in academia as an objective gender-blind meritocracy, focuses on innate individual traits or personal choices and decisions (e.g., family formation) to explain divergent career outcomes, without considering the institutional context that may influence these choices and career trajectories (e.g., Ceci *et al*, 2014). Scientific achievement, the cornerstone of academic success, according to this point of view, is judged against objective criteria and with quantitative metrics, irrespective of gender. If some women are less successful it is because they are simply less productive, divert their attentions elsewhere, or choose to not fully commit to their careers (Ceci *et al*, 2014). And, after controlling for productivity and personal or family characteristics, there is no evidence of gender bias in academic career attainment (Ceci *et al*, 2014). Thus, according to this "women as deficient" model, to fix the problem we need to fix the women (Rosser, 2004).

Of course, meritocracy as a concept in itself is vulnerable to critique as the reliance on seemingly "objective" criteria in the evaluations of a scientist's cumulative accomplishments does not automatically translate into gender-neutral decisions (Acker, 2006; O'Connor and O'Hagan, 2016). Universities are gendered organizations in that judgments on what constitutes scientific quality or what activities are deemed valuable often reflect implicit bias along gender lines (van den Brink and Benschop, 2011). The image of the ideal scientist continues to be framed around largely masculine characteristics, such as competitiveness and complete dedication to the job, yet are presented as gender-neutral (Acker, 1990; Cech and Blair-Loy, 2010). This puts women at an evaluative disadvantage as lacking competence or commitment. Evaluation criteria are often unevenly applied in academia (O'Connor and O'Hagan, 2016), and according to Foschi (1996; 2006), assessments of ability are often influenced by the social status of the performer, leading to double standards in performance evaluations. Because men enjoy a higher social

status than women, this tendency leads to the systemic downplaying of the accomplishments or competence of women even if there is no objective or measurable difference in ability between men and women. Numerous studies have demonstrated how gender bias in evaluation influences hiring and advancement decisions that lead to divergent career outcomes for men and women scientists. This dynamic has been observed at all career stages, from the hiring of lab managers with undergraduate degrees (Moss-Racusin *et al*, 2012) to the recruitment and promotion of associate and full professors (van den Brink and Benschop, 2011; Nielsen 2016). It also has been reported in teaching evaluations of academics (MacNeill *et al*, 2015), for invites to prestigious colloquia at top universities (Nittouer *et al*, 2018), and other forms of recognition that contribute to the construction of excellence (van den Brink and Benschop, 2011; O'Connor and O'Hagan, 2016).

It is not uncommon to find statements in the STEM literature regarding the lower productivity of women (see citations in Leahy, 2007 and Ceci *et al*, 2014) – a contention that is not entirely undisputed (Cameron *et al*, 2016) – that are then invoked as a supply-side explanation for slower advancement (Ceci *et al*, 2014). Such claims often lack further exploration of structural or institutional conditions that may have caused differences in productivity between men and women faculty, such as academic division of labor and high demands for non-research activities, exclusion from information and collaboration networks, or limited mobility due to family obligations (Rosser, 2004). However, parallel studies in the U.S and Europe, using an array of productivity metrics of early-career (Weisshaar, 2017) and mid-career academics (van den Besselaar and Sandström, 2016) concluded that differences between men and women's career advancement are often not explicable on the basis of differences in productivity, but are due to other factors, including gender bias in the hiring and promotion process of academic staff.

In recent years significant evidence supports the conclusion that that institutional barriers have prevented women from having a level playing field, and that the scarcity of women in the upper levels of academia is less the result of their individual failure than a consequence of systemic barriers present within academic settings (Rosser, 2004). The NSF-ADVANCE Program, which supported research into the recruitment, retention, and advancement of women in STEM, reflects this sea change in perspective at

the national level. The program was initiated in 2001 specifically to clarify structural barriers and seek institutional solutions to the underrepresentation of women in the STEM disciplines (Stewart *et al*, 2007)

The ADVANCE Program

Our university was part of the second wave of NSF Transformational Grants funding and shares many of the programmatic components and study approaches with other early ADVANCE projects (Stewart *et al*, 2007). Among the various goals of the NSF-ADVANCE project at this university (2003-2008), three aspects were particularly pertinent to the mid-career advancement issue: (1) *data transparency*, i.e., the development of a demographic database to provide an objective and tractable record of the gender distribution among faculty ranks over time; (2) *awareness and intervention* through workshops, panel discussions, and departmental meetings sanctioned by the university administration and intended to provide information to all faculty on the promotion process; and (3) *policy changes* such as clarifying post-tenure review in the Faculty Policy, which at this university contains a detailed delineation of all policies and procedures specifically related to faculty.

The ADVANCE team began tracking faculty data in 2002 and was instrumental in compiling and digitizing the initial faculty database in 2007 for STEM, as no centralized accessible digital database of university personnel was available prior to this date. Maintenance and annual update of this university-wide database has been institutionalized since then and is now under the purview of the Office of Analysis, Assessment and Accreditation (AAA). The centralized collection, maintenance, and annual update of this data base has enabled objective reporting of the proportion of women (and racial/ethnic minorities) in various tenure and non-tenure track faculty and leadership positions, and has allowed us to quantify longitudinal changes in faculty composition. Data tracking has been identified by other institutional analyses as one of the key mechanisms supporting institutional transformation as data transparency allows the identification of the problems related to gender representation and provides indicators by which to monitor progress towards institutional goals and effectiveness of interventions (Rosser and Chameau, 2006; Frehill, 2007; Stewart *et al*, 2007; Corell, 2017).

A second component of this ADVANCE project focused on improving tenure and promotion processes by creating greater transparency in institutional practices. Secrecy or ambiguity surrounding performance expectations, lack of clear guidelines and misinformation with regards to promotion decisions has emerged as a common theme in numerous other ADVANCE studies (Sturm, 2006; Freehill, 2007; Stewart *et al*, 2007; Banerjee and Pawley, 2013). Codified university policies related to faculty at this university, hereafter referred to as “Faculty Policy”, describe the composition and authority of the Faculty (including definitions of categories, academic units, and department heads); define the Faculty Senate and purview of its committees; and define tenure, eligibility, the probationary period for tenure; faculty search procedures as well as due process and complaint procedures. While Faculty Policy clearly outlined processes and procedures for tenure, processes related to promotion from associate to full professor were less clear. Information on the steps towards promotion to full professor were generally less formalized and were conveyed mostly informally through (largely male) social networks, rather than transparently and systematically to all faculty through codification in Faculty Policy.

The ADVANCE team identified five departments (at least one from each of the four STEM colleges) that were willing to work with ADVANCE to reflect on and improve gendered interactions. An outside organizational consultant who had previously worked with business organizations on gender issues, and one ADVANCE team member first interviewed the majority of faculty in each department. The ADVANCE team identified promotion as a significant problem through interviews with STEM women who expressed frustration about the opaqueness of the promotion process, exemplified by statements such as “This University / College / Department does a good job of mentoring faculty through tenure After tenure no one talks to you again”. Such statements were often followed by comments about not knowing how to decide when to go forward for promotion.

In addition, ADVANCE conducted department climate surveys to further identify perceived barriers to faculty, especially women’s success and to quantify metrics of departmental climate quality. Hiring rates of women versus men over the previous five years were also tracked and presented within the context of national graduation rates of PhDs within each department’s discipline. ADVANCE worked to

modify the academic culture by working with search committees to improve gender balance in the candidate pools and decrease bias in candidate selection. Departmental and university-wide workshops and panel discussions were held to provide information to all faculty on expectations and actual steps in the promotion process, thus creating much-needed transparency especially with respect to the promotion to full professor. In addition to increasing the transparency of the promotion process, the USU ADVANCE Program provided small grants to faculty members preparing for promotion to full professor. These were not continued beyond the award period.

In response to faculty feedback regarding missing guidelines on promotion review initiation, ADVANCE drafted and guided policy changes through the Faculty Senate approval process. Faculty Policy changes were implemented in 2005 that more clearly codified the post-tenure review procedures. Specifically, the Faculty Policy now stipulates that no later than three years after tenure (or earlier at the request of the tenured faculty member), a post-tenure review committee must be assigned to each faculty member. This committee must meet with associate professors at least once within the first three years after tenure to “provide guidance to the faculty member relative to the criteria for promotion to professor”. This formalization of the post-tenure review timeline ensures that accomplishments of all tenured faculty are reviewed in a timely manner and that evaluations of faculty portfolios are framed within the context of potential promotion.

During the ADVANCE program, the university administration was characterized by high turnover, with nine individuals serving in the three upper administrative positions closely collaborating with the ADVANCE program (President, Provost and Vice Provost for Faculty and Academic Affairs) and ten individuals serving as deans in the four STEM colleges. Administrators varied in their support of the ADVANCE Program and frequent turnover of positions made it difficult for the program to find consistent support. The economic recession severely disrupted university operations and occupied the time and effort of administrators in 2007 and 2008. Consequently, implementation of this post-tenure review policy was sometimes inconsistent during leadership transitions, but more recent provosts have shown a commitment to working with departments to ensure consistent implementation of this policy.

Methods

This study used secondary faculty data (AAA census data) for 2008 and 2014, including college, gender, date and rank at hire, and dates of promotion. During the ADVANCE project, promotion rates prior to 2008 were extracted from personnel files. The proportional representation of women in assistant, associate, and full professor rank was compared to the NSF data on gender composition of PhD recipients in 2009-2013, 2004, and 1999, respectively. In addition, the provost office provided an anonymized list of promotions to full professor by college between 2008 and 2015, which also included gender, date and rank at hire, and year of tenure. The 2008 census data was used retrospectively and examined the past career trajectory of those faculty who were listed as full professors in the 2008 census. It could not, by its very nature (static snapshot), provide any information on promotion dynamics of faculty who had left the university prior to 2008. Those faculty who were full professors in the 2008 census are considered to have been promoted using the pre-ADVANCE institutional practices in faculty promotions. The 2014 census and the 2008-2015 promotion data were used to reflect post-ADVANCE institutional practices as they pertained to the promotion to full professor.

Because data on entire faculty populations (census data) were used, rather than samples, averages were calculated by gender and reported at face value, rather than being analyzed statistically. Furthermore, variability (range) in the data on time in associate rank until promotion to full professor was in itself pertinent to illustrate the level of consistency in the promotion process and changes over time. All data was analyzed using SPSS (Version 21).

In fall 2016, an online Qualtrics survey was distributed to faculty in the colleges of Science, Natural Resources and Engineering that included demographic information and core work climate-related questions from the previous ADVANCE surveys (2003 and 2011). In addition, tenured faculty were queried on their perceptions of the promotion process to full professor. The survey response rate was 32%. This response rate is consistent with response rates from comparable published studies based on survey research. A meta-analysis of survey research found that individual and organizational-based survey response rates average 36% to 53% with a standard deviation of around 20% (Baruch and Holton,

2008). Our survey population was comprised of 19% non-tenure track faculty, 25% untenured faculty, 17% associate professors, and 39% full professor, capturing around 28% of the tenured faculty in the three colleges. Men and women respondents were represented in a two to one ratio overall and in all ranks, except for non-tenure track faculty, which were more evenly distributed by gender.

Results

Status of women

The first wave of women hires within STEM colleges at this institution took place between 1988 and 1995. In the 2008 census there were a total 264 male and 62 female tenure-track and tenured faculty (TT&T) in STEM. Women represented less than 20% of TT&T faculty in the STEM colleges at the university, with only 3% of STEM women faculty holding the rank of full professor. In 2008 the ratio of men over women in this rank was 12 to 1 (Figure 1). By 2014, the total number of women STEM faculty had increased to 75 (vs 251 men), representing 23% of all STEM TT&T faculty. Increases were most noticeable in the higher ranks with the number of women associate professors increasing from 22 in 2008 (22% of all associate professors) to 29 in 2014 (28% of all associate professors), while the number of women full professor increased from 11 in 2008 to 19 in 2014, representing respectively 8% to 13% of all faculty in that rank.

Time as associate until promotion to full professor

Retrospective analysis of the 2008 census data indicated inconsistent mid-career trajectories for all STEM faculty, and a large gender gap in the time as associate professor until promotion to full professor. While it took men on average 6.5 years as associate professor to be promoted to full professor (range 1-22 years), women took on average more than two years longer (mean 8.75 years, range 4-12 years). Cumulative distributions of time in associate professor rank by gender (Figure 2) show that 41% of male associate professors were promoted to full professor within 5 years of being tenured, while only 25% of the female associate professors attained the rank of full professor by that time. The majority (81%) of men but only a little over one-third (37% for) of women had been promoted after 8 years in the

associate professor rank. Characteristic of the pre-ADVANCE cohort was the large variability in time to promotion for both men and women, suggesting a highly inconsistent promotion process.

One possible mechanism that may have contributed to this variability within and between gender groups is the rank at hire and associated employment-related negotiations. Indeed, faculty who started their university appointment as associate professors took significantly less time until promotion to full (Mean = 5 years, median = 4 years when hired as associate professor vs mean = 7 years, median = 6 years for those hired as assistant professor; Kruskal-Wallis non-parametric test at $p < 0.05$). The 2008 census data revealed that all but two women faculty (who were originally hired in administrative ranks) had started their appointment as assistant professors, while hiring rank was more variable among male STEM faculty. Consequently, rank at hire constituted an indirect gender effect on career advancement.

Few women were promoted to full professor prior to 2003 (Figure 3). Between 2001 and 2005, only 4 women were promoted, representing 11% of the cohort of faculty promoted to full professor in that timeframe. This partly reflected the relative scarcity of eligible women faculty hired before the late 1980s. However, there were at least six faculty women who had been hired prior to 1991, and should have been under consideration for promotion [assuming “normal” 6 years pre-tenure and 6 years as associate professor (Britton, 2010)]. It is noteworthy that by 2008 these women had still not reached the full professor rank, despite faculty appointments spanning 17 to 30 years. Because the full professor population in 2008 likely reflected past legacies and potential variability in procedures over time, a direct gender comparison was made by year of hire (Figure 4). Once again, this comparison revealed high variability in faculty promotion outcomes, both for women and men. The data also showed that within the same hire cohort, the average time from associate to full professor was always longer for women compared to men.

Promotions of women to full professor started to occur more frequently and at higher rates with the onset of the ADVANCE project, and this trend has continued through the present (Figure 3). At the same time, the relative proportion of women among those promoted also increased from 28% in the period 2006-2010 to nearly one third in the most recent 5-year period (2011-2015). Since 2008, men and

women have been promoted in roughly a two to one ratio (33 men vs 16 women). There has also been a decline in variability in career outcomes for all faculty and a closing of the gender gap (Figure 5), especially for the more recent hires. For those promoted since 2008, average time as associate professor was just under 9 years for both men and women (median 7 years for men; 8 years for women). After removing the 25% that were hired prior to 1996 – considered pre-ADVANCE legacies given the time since hire was greater than 12 years and they should reasonably have been considered for promotion – patterns were even more favorable. The average time as associate until promotion to full professor was 13 years from women (range: 10-18 years) and 15 years for men (range 11-25 years) in the legacy group. The more recent hires (i.e., those hired since 1996) have been moving through the process more swiftly and consistently (on average in 7 years) and any gender gap has disappeared for these cohorts (median 7 years for women, range 5-9 years; median 6 years for men, range 3-14 years) (Figure 5). The changes in promotion dynamics between 2008 and 2014 resulted a doubling of the number of female full professors in STEM (from 3% to 6% of TT&T faculty), such that the ratio of male to female full professors is now 6.5 to 1 (Figure 1).

Past legacies and changes in promotion dynamics are further illustrated in overall time to promotion (years in assistant and associate professor rank combined) before, during and after the ADVANCE program. The period prior to 2003 (before ADVANCE) reflects a male-dominated legacy, with more than two thirds of the (male) faculty promoted to full professor within 12 years of being hired, and only 31 % of the men taking longer to achieve that rank. During and following ADVANCE, promotion standards were raised and portfolios were scrutinized more systematically. This resulted in some men moving through the process more slowly, illustrated by the equal proportion of men take both longer and less than 12 years at the university before promotion to full professor. On the other hand, only one-quarter of women achieving full professor rank have done so within 12 years of being hired (22 % 2003-2008; 29% after 2008).

Women's perception of the institutional climate

The 2016 survey indicated significant improvement in faculty attitude vis-à-vis the climate at the university compared to similar surveys conducted at the onset (2003) or immediately after (2011) the ADVANCE project (Figure 6). Survey results for both men and women faculty were similar between 2003 and 2011, with women generally expressing lower job satisfaction than men. The improvement in faculty morale observed in 2016 was most pronounced for women. In 2016, the majority of the women expressed job satisfaction (87%) and indicated that they felt valued (74%), fit in their respective departments (65%) and felt they regularly received all important information needed to conduct their work. This represented a 20% increase in positive responses compared to the pre-ADVANCE survey. Fewer women reported being excluded from informal networks (44% in 2003 vs 26% in 2016). In addition, metrics signifying distrust or disappointment with the university, such a frustration over their treatment, anger, or feelings that promises had not been kept, simultaneously declined and virtually disappeared (< 5% of women respondents).

Faculty Perception of the promotion process

In 2016, almost a decade after the ADVANCE project came to an end, the majority of all tenured faculty (64%) agreed that guidelines, criteria, and expectations related to the promotion process had generally been communicated clearly to them. There was no significant difference in response by rank ($\chi^2=0.443$, $p=0.382$) or gender ($\chi^2=0.000$, $p=0.647$). Furthermore, over 80% of the male faculty indicated that guidelines to promotion, committee formation, standards of excellence and portfolio preparation were clearly communicated by their respective departments. The proportion of women responding positively to these questions (i.e., selecting “extremely clearly” and “somewhat clearly”) were lower compared to men, but gender differences were not statistically significant (promotion guidelines: 82% for men vs 64% for women, $\chi^2=1.725$, $p=0.631$; committee formation: 90% vs 57%, $\chi^2=5.475$, $p=0.140$; standards of excellence: 82% vs 79%, $\chi^2=4.136$, $p=0.388$; binder preparation: 79% vs 71%, $\chi^2=1.343$, $p=0.719$). There were statistically significant differences in response distribution between associate and full professors, with the latter more frequently selecting “extremely clearly”, whereas associate professors were slightly

more judicious in their responses, selecting “somewhat clearly,” 45-55% of the time (promotion guidelines: $\chi^2=13.548$, $p=0.004$; committee formation: $\chi^2=13.548$, $p=0.004$; standards of excellence: $\chi^2=8.141$, $p=0.087$; dossier preparation: $\chi^2=2.036$, $p=0.565$). Nevertheless, almost all associate professors in the survey (87% of men and 80% of women) indicated intent to go up for promotion and a similar proportion (71% of men and 75% of women) expressed confidence in a successful outcome, with women actually expressing greater confidence (75% of women selected “very confident” vs 27% of the men). None of the patterns were significantly influenced by gender of the faculty.

Discussion

The initial climate survey conducted in 2003 by the ADVANCE team into the perceived barriers to career attainment among STEM faculty revealed the mediating effect of departmental climate on lower job satisfaction of women faculty (Callister, 2006). Confusion about promotion criteria and process (Fox and Colatrella, 2006) or lack of access to information (Hult *et al*, 2006) have been documented as causes for lower job satisfaction and career attainment for women faculty in STEM. This study shows significant post-ADVANCE improvement in women’s perception of the academic climate for advancement and provides evidence of positive feelings towards and confidence in the promotion process by the majority of tenured faculty, irrespective of gender. The differences in pre-ADVANCE job satisfaction between men and women, and the overall improvement in faculty morale post-ADVANCE, especially for women, are consistent with findings from a similar longitudinal ADVANCE study at Ohio State University (Bystydzienski *et al*, 2017). The slightly more positive responses of full compared to associate professors likely reflect situational differences in perception between those who have successfully navigated the process and those still facing the promotion decision.

The institutional practices prior to 2008 led to inconsistent outcomes for both men and women, as indicated by the large variability in time to promotion to full professor. It also clearly disadvantaged women faculty, as it took longer for them to be considered for promotion. The first women moving through the ranks were largely in token positions within their respective departments, which is often associated with hyperscrutiny and negative evaluation bias (Kanter, 1977) such that women have to work

harder and accomplish more in order to be recognized compared to similarly positioned male colleagues (Rosser, 2004). Exclusion from critical information networks and the lack of senior role models further contributes to women being overlooked as potential candidates for promotion in the absence of clear guidance on process and timeline (Rosser, 2004). An empirical study combining personnel data with faculty interviews by Roos and Gatta (2009), reported similar large inequities and subtle gender discrimination in the promotion process, as (some) men but not women were encouraged to seek early promotion. This dynamic is suggested in our study by the observation that the majority of men promoted to full professor prior to 2003 did so in less than 12 years after being hired. A study in France further showed that being overlooked and lingering in rank tends to reduce one's chances of future promotion to professor (Sabatier *et al*, 2006). The initial focus of the ADVANCE project was to move some of these legacies through the process.

The impact of gender differences in the rank at hire on subsequent career trajectories has also been documented in other universities (Roos and Gatta, 2009) and research institutions (Sabatier *et al*, 2006). Merton (1973) refers to this dynamic as the “Matthew effect”, the self-reinforcing process that increases inequality when higher-status individuals (generally men) are given the benefit of the doubt and accrue more recognition for their scientific contributions than lower status individuals. Conversely, similarly situated women, according to Valian (1999), tend to accumulate disadvantage. These tendencies underscore the crucial role of early career recognition (and decision at hire point) to a scientist's future success via the positive feedback between status, resource access, and subsequent productivity (DiPrete and Eirich, 2006). Several empirical studies in STEM have documented that men often have greater access to institutional resources and support (Rosser, 2004; Duch *et al*, 2012; Ceci *et al*, 2014) and such differences in resource allocation can present indirectly as gender differences in career trajectory (Roos and Gatta, 2009). When there is a high level of ambiguity during pre-hire negotiations, gender gaps in outcomes tend to be more pronounced (Bowles *et al*, 2005). Women often find themselves at a disadvantage when they cannot negotiate their start-up packages with the same vigor as their male counterpart without being perceived negatively (Williams and Dempsey, 2014). Double standards in

portfolio evaluations downplaying the accomplishments of women may also contribute to gendered hiring practices (Foschi, 1996; 2006; O'Connor and O'Hagan, 2016).

The ADVANCE project had a positive effect on the number of women hired within STEM (Hult *et al*, 2008). By 2014, the relative proportion of women in STEM departments was consistent with the gender composition of the employment pool for associate professors (% women PhD recipients in 2004) and was at or above availability for assistant professors (average % women PhD recipients for period 2009-2013) (Burelli, 2008; Van Miegroet, 2018). This had a twofold positive effect on the mid-career dynamics for women: (1) women were no longer in token positions; and (2) the pool of women eligible for promotion increased gradually over time. Importantly however, increased representation of numerical minorities is necessary but insufficient to transform the organization (Acker 1990). Thus, additional efforts by the ADVANCE team in transforming institutional climate were critical.

The presence of ADVANCE on campus made the issue of gender inequality more visible by collecting and making transparent demographic and promotion data. The latter has been an essential project component of all ADVANCE initiatives, both as a diagnostic tool and means of assessing progress towards institutional gender equity goals and intervention effectiveness (Sturm, 2006; various chapters in Stewart *et al*, 2007). Data are now updated annually and the process of data collection and visualization has become institutionalized. The 2003 climate survey revealed the critical role of departmental climate on job satisfaction, especially among women in STEM (Callister, 2006). Specifically, women faculty cited a lack of access to information as one cause for lower job satisfaction (Hult *et al*, 2006), a complaint commonly expressed by faculty at other ADVANCE institutions (Sturm, 2006; Frehill, 2007; Stewart *et al*, 2007; Banerjee and Pawley, 2013). The workshops and dialogues on campus transformed the process of informal and inconsistent information transfer to the privileged network-connected and those “in the know” into a more objective and egalitarian information flow. These efforts also created greater transparency in expectations and promotion procedures that seemed to have had an overall positive influence on the promotion trajectories both in terms of overall reduction in the length of time until promotion to full for all STEM faculty and in reducing differences in career

attainment between male and female STEM faculty. These workshops have become institutionalized and are still ongoing, albeit at lower intensity and frequency than during ADVANCE, and are largely organized by the provost's office.

While these information transfer sessions were instrumental in alleviating faculty anxiety and improving morale, enduring changes in promotion dynamics were achieved through Faculty Policy language in 2005 that systematized the process of post-tenure review and clarified the faculty's right to such review. After an initial transition period during which STEM college administrators were held accountable through queries by ADVANCE team members about the relative compliance with the requirement of post-tenure review within three years, this codified procedure is now routinely implemented across colleges. Consistent with the literature (Reskin, 2000; Fox and Colatrella, 2006), this study indicates that greater transparency, accountability and formalization in the post-tenure review process initiated by ADVANCE improved the promotion outcomes for both men and women and also significantly reduced the gender gap. In other words, the codification of procedures and responsibilities neutralized the subjectivity stemming from variable departmental climates. Analysis of the 2016 faculty survey seems to confirm greater overall job satisfaction of women and a positive attitude towards the promotion process among all tenured STEM faculty.

Another key element in the sustainable success of the ADVANCE program lies in the requirement by NSF to include high-level university administrators as project collaborators and in the role of change actors (Sturm, 2006). The provost office was represented on the ADVANCE team by an associate vice provost, who had specific role responsibilities related to gender equity and who oversaw many of the activities initiated by ADVANCE. Between 2004 and 2005, one of the co-PIs on the project had a dual leadership role as Dean of one of the STEM colleges and as Vice Provost for Women's Issues. Her successor, who served as Vice Provost for Development and Diversity between 2006 and 2010 was instrumental in the organization of many of the provost-sponsored activities, and in 2010 became the Director of the newly established Center for Women and Gender. Correll (2017) argues that change initiatives within organizations are most effective when leadership is involved in shaping the process.

Indeed, the involvement of upper-level administrators lends legitimacy to the institutional intervention because they have the credibility and influence within the organization, possess the power to facilitate policy changes and have the authority to require adherence to these policy changes by all members of the institution (Sturm, 2006).

This study demonstrates that marked improvements in the upward mobility of women in STEM were achieved by ADVANCE through a combination of several factors: (1) greater transparency in the institutional expectations and necessary steps towards promotion; (2) reduced barriers to information flow; (3) standardization and codification of the promotion process, and (4) inclusion of university leadership as change actors. Yet despite the positive effect of the intervention strategies from ADVANCE, including increased recruitment of women faculty in STEM and accelerated promotion rates of women associate professors, demographic modeling by Bakian and Sullivan (2010) suggests that the ratio of men to women in the full professor ranks is not likely to reach the composition of the employment pool in the foreseeable future at this institution. While the proportional representation of women has improved following ADVANCE in some faculty ranks, the current (skewed) faculty population structure, with men dominating the full professor rank, is likely to persist for several decades through demographic inertia. In order to completely overcome demographic inertia (i.e., break the entrenched population structure), two crucial conditions are necessary (Bakian and Sullivan, 2010). First, positive efforts towards increased recruitment and promotion rates of women initiated through ADVANCE must be sustained in order to avoid a deceleration in the current positive trajectory toward greater women's representation in the faculty ranks. Second, a change in hiring practices, particularly increased recruitment of women at the associate and full professor level, is necessary to achieve greater gender balance in the highest faculty ranks at this institution (Bakian and Sullivan, 2010).

Conclusions and Implications

On the basis of faculty census and promotion data between 2008 and 2014, and multiple waves of climate surveys, this study was able to demonstrate the impact of the ADVANCE project on the mid-

career upward mobility of women faculty in STEM at a single doctoral research university where research productivity rather than teaching, advising, mentoring, or service is prioritized in faculty evaluations for promotion. The relative proportion of women faculty in the associate professor rank increased from 22% in 2008 to 28% in 2014, with corresponding increase from 8% to 13% for full professors. There was a noticeable upswing in the number of women promoted full professor post-ADVANCE, such that nearly one third of those promoted to full professor now are women. A more equitable working environment for women was achieved through a combination of (1) data collection to highlight problem areas and provide indicators of progress towards gender representation targets; (2) systematic and deliberate disseminations of crucial information to all faculty to counteract the impact of informal networks and dispel myths and misinformation; (3) formalization and codification of post-tenure procedures to counteract ambiguity in decision making; and (4) the active engagement of university leadership in the transformation of institutional practices towards greater transparency, consistency and accountability. Our findings suggest that the variability in promotion outcomes was not a gender issue *per se*, and that a program aimed at improving the working environment for women faculty in fact benefited all faculty irrespective of their gender. This was borne out both by actual promotion data and by faculty survey responses that signaled a noticeable improvement in faculty morale, irrespective of gender.

ADVANCE efforts had a transformative and lasting influence on institutional practices. As institutional climate matters to job satisfaction (Callister, 2006) and career outcomes for women in STEM (Valian, 1999; Rosser, 2004), the critical question becomes “How can lasting changes in academic climate be achieved?” The effectiveness and sustainability of this ADVANCE project was in part achieved by adhering to many of the recommendations summarized in the ADVANCE synthesis by Stewart *et al* (2007) and by following the sequence of steps outlined in the “small wins model” for institutional change outlined by Correll (2017). Throughout the program, university administrators at various levels were engaged as collaborators and change actors. While the program at large endeavored to change institutional practices that benefited faculty, change could not be achieved without making leadership aware of the uneven gender representation within STEM and its potential causes (education,

diagnosis) and making them active participants in the design and implementation of the change process. For example, institutionalization of many of the project activities (e.g., data collection, information dissemination through documents and workshops) was possible only through the commitment by the provost's office to allocate resources to safeguard their continuity. Because department climates and practices vary, oversight from college and/or university-level administrators is necessary to guarantee systemic change and consistency in implementation of procedural changes. This finding is consistent with research by Goodwin *et al* (1998) demonstrating that decision makers are less likely to show cognitive bias when they have a stake in the outcome or are held accountable for their decisions and decision criteria, especially to those in power. High turnover in leadership and university administration during the ADVANCE period somewhat hampered consistent and uniform implementation of the post-tenure review policy, but more recent provosts have shown greater commitment to adherence to Faculty Policy. As a result, standardization of policy and practice is being implemented across the university including in non-STEM departments and colleges.

The sustainability of the program rests on two essential components: (1) it created greater awareness of actual gender gaps (by collecting quantitative data) and clarified expectations of promotion (through information workshops); and (2) it put in place policies that translated these findings into objective and enforceable action items. While the first step was essential in making problems visible and creating greater institutional attentiveness to gender equity at the departmental, college, and university levels (at least temporarily) (Sturm, 2006), this in itself can prove ineffective in achieving gender equity if not associated with structural (i.e., policy) changes (Kalev *et al*, 2006). Furthermore, a faculty population structure characterized by dominance of men in the highest ranks cannot be alleviated in the short-term. Fundamental faculty composition changes overcoming this demographic inertia are possible over longer time periods only and require that gender-balanced recruitment and promotion efforts initiated during ADVANCE be maintained, and that recruitment of women also includes hiring at associate and full ranks (Bakian and Sullivan, 2010).

This ADVANCE project had a systematic and sustainable influence on the institutional promotion practices despite the modest funding size of the promotion to full program, by responding to institution-specific conditions and tailoring interventions to the institution's culture (as per Sturm, 2006). While previous research has shown that gender bias permeates the evaluation of academic performance, this study suggests that deliberate changes in institutional practices can indeed limit the impact of gender bias on career outcomes. To achieve institutional gender equity goals, the project first identified the specific obstacles to the career success of women within the context of the institution and then worked to remove sources of inequality appropriate for the institution. In this case, change occurred through modification of the Faculty Policy, the locus of all personnel procedures at this particular university. For example, the ADVANCE team changed faculty policy to expand a smaller program and create a university wide Promotion and Tenure Ombudsperson program. This requires one trained faculty member, who is not on the promotion and tenure committee, to be present as an observer tenure meetings to ensure that all committees follow policy and with the power to stop the meeting if the committee violates policy. Furthermore, the ADVANCE team changed university policy to create a standing Faculty Senate committee charged with focusing on gender and ethnic equity and diversity. This committee is charged with retrieving university data and presenting an annual update to the Senate on how each college is performing on several gender and minority metrics.

Our findings suggest that other similar doctoral research universities can reduce gender disparities in the advancement to full professor by increasing the visibility of gender disparities, pursuing transparency in the promotion process and standardizing policy and practice related to promotion for all faculty. However, the NSF-ADVANCE program aimed to increase the representation and advancement of women faculty in STEM across all institutional types, not just at large research universities. According to the aims of the program, "ADVANCE is interested in supporting a range of non-profit academic institution types" including but not limited to community colleges, minority-serving institutions and primarily undergraduate institutions. Though women at different types of institutions may face variable challenges, Rosser (2004) found that irrespective of institutional variability, women faculty in STEM are

consistent in their response about barriers and challenges to their respective academic career. Britton (2010) further argues that organizational demographics inherent to the STEM disciplines, with men numerically dominating most decision points, is likely to impact the promotion dynamics for women at most IHEs. Therefore, we think that our findings are relevant to the women's experiences at other IHEs in that promoting standardization and transparency in the promotion process can reduce evaluation bias and increase the representation of women in STEM.

Fully interrogating the various mechanisms through which other types of institutions can facilitate the advancement of women into the full professor ranks requires further research. Gender inequality is seldom experienced by women in STEM as a uniform oppressive climate according to Britton (2017). Rather, it is contextual and emerges through interactions, organizational structures, and workplace culture. Thus, efforts to foster gender equity are most effective when placed within a specific organizational context (Sturm, 2006; Britton, 2017). However, our study provides some insights into the general path that other institutions might follow. Most institutions have criteria and guidelines that govern promotion for faculty. Thus, focusing efforts on clarifying those criteria and standardizing the guidelines are vital for reducing gender disparities in advancement. First, stakeholder and change agents can begin by identifying aspects of the promotion process that are subjective, opaque or non-standardized. For example, identifying gender differences in the time to promotion, in the likelihood of pursuing promotion, and in differences in rank at hire can illuminate where in the process bias might occur. Is post-tenure review automatic or institutionalized for all faculty or can faculty opt for a review? If the latter, then it is likely that departmental climates vary in their support of women's advancement, with some privileging men faculty in formal or informal ways that may be alleviated by implementing a mandatory automatic review for all faculty. Second, stakeholders can build administrative buy-in by making gender disparities at any point in the process visible and transparent. Data collection and dissemination, sanctioned by university leadership, plays a key role in identifying gendered promotion dynamics and in facilitating institutional change. This is because data transparency can serve as a mechanism of accountability and "nudge" decision makers to adopt fairer and more equitable practices. Administrative allies, including

institution-specific governance structures such as faculty senate, can assist in implementing policies in a systemic way (Sturm, 2006).

Finally, stakeholders can pursue sustainable change by modifying existing policies where they exist or introducing new policies and procedures where they are needed.

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Figure captions

Figure 1. Distribution of STEM faculty by rank and gender in 2008 (first census) and 2014.

Figure 2. Cumulative distribution of number of years in associate professor rank prior to promotion for men and women in STEM who were full professors in 2008.

Figure 3. Number of women in STEM promoted to full professor between 1988 and 2015 (Note: two women promoted to full in 1995 had left university prior to 2008 census).

Figure 4. Average time (in years) in associate professor rank until promotion by year appointment at university for men and women who were full professor in 2008 (Note: n=1 for women except in 1993 hire year, where n=2)

Figure 5. Average time (in years) in associate professor rank until promotion by year appointment at university for men and women promoted between 2008 and 2015.

Figure 6. Percentage of male and female faculty who agreed with the statements (selected “strongly agree” or “Agree”) in the 2003 (Pre-ADVANCE) and 2016 (Post-ADVANCE) faculty climate survey. (*) for the two last categories comparison between 2011 and 2016 survey.



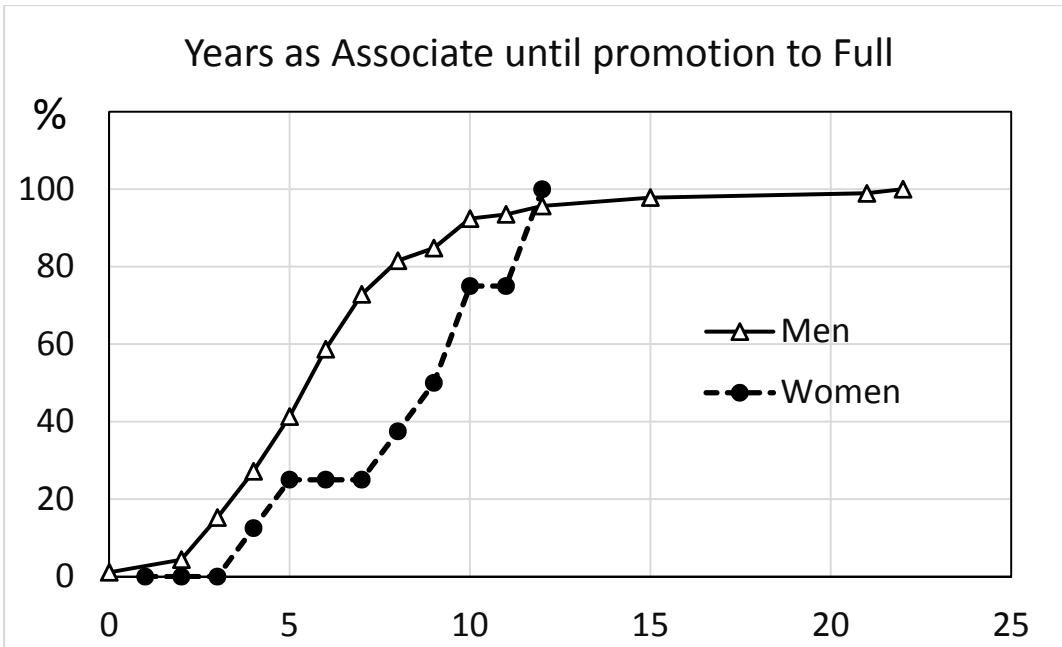


Figure 2. Cumulative distribution of number of years in associate professor rank prior to promotion for men and women in STEM who were full professors in 2008.

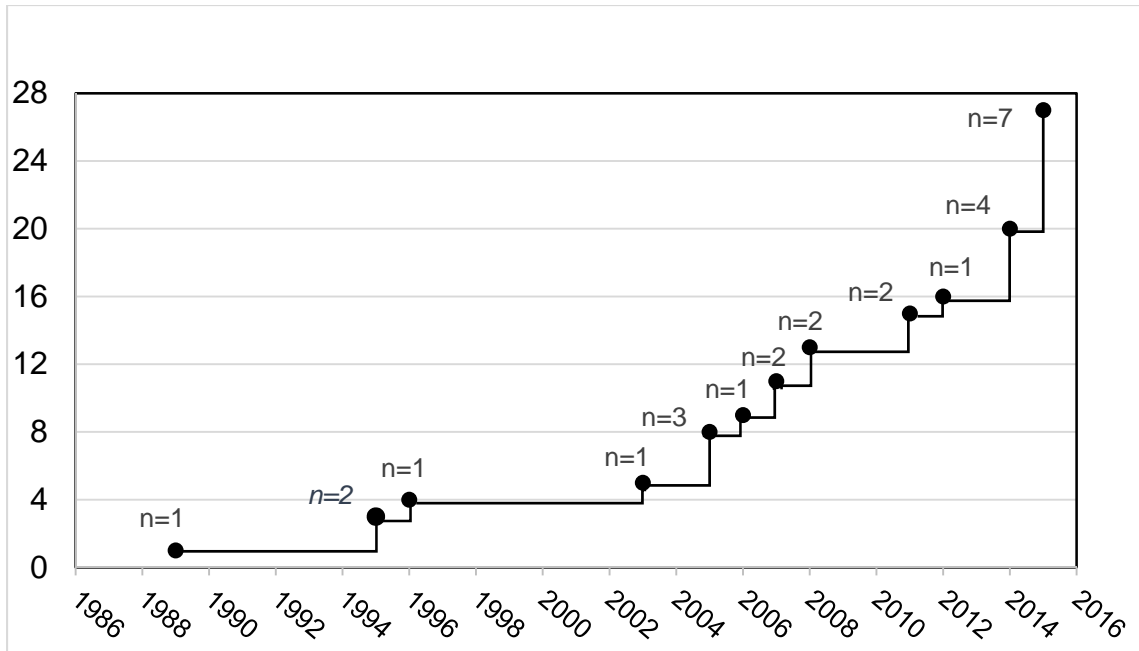


Figure 3. Number of women in STEM promoted to full professor between 1988 and 2015 (Note: two women promoted to full in 1995 had left university prior to 2008 census).

Average years as Associate until promotion to Full Professor by hire year - 2008 census

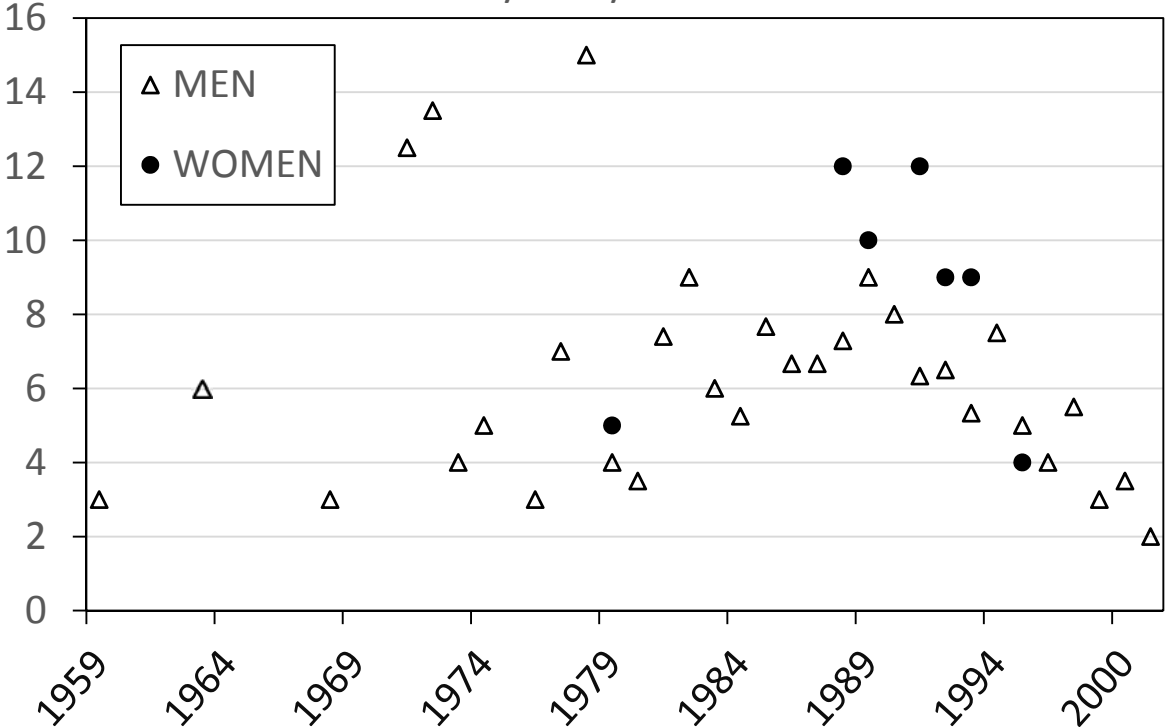


Figure 4. Average time (in years) in associate professor rank until promotion by year appointment at university for men and women who were full professor in 2008 (Note: n=1 for women except in 1993 hire year, where n=2)

Average years as Associate until promotion to Full Professor by hire year for 2008 -2015

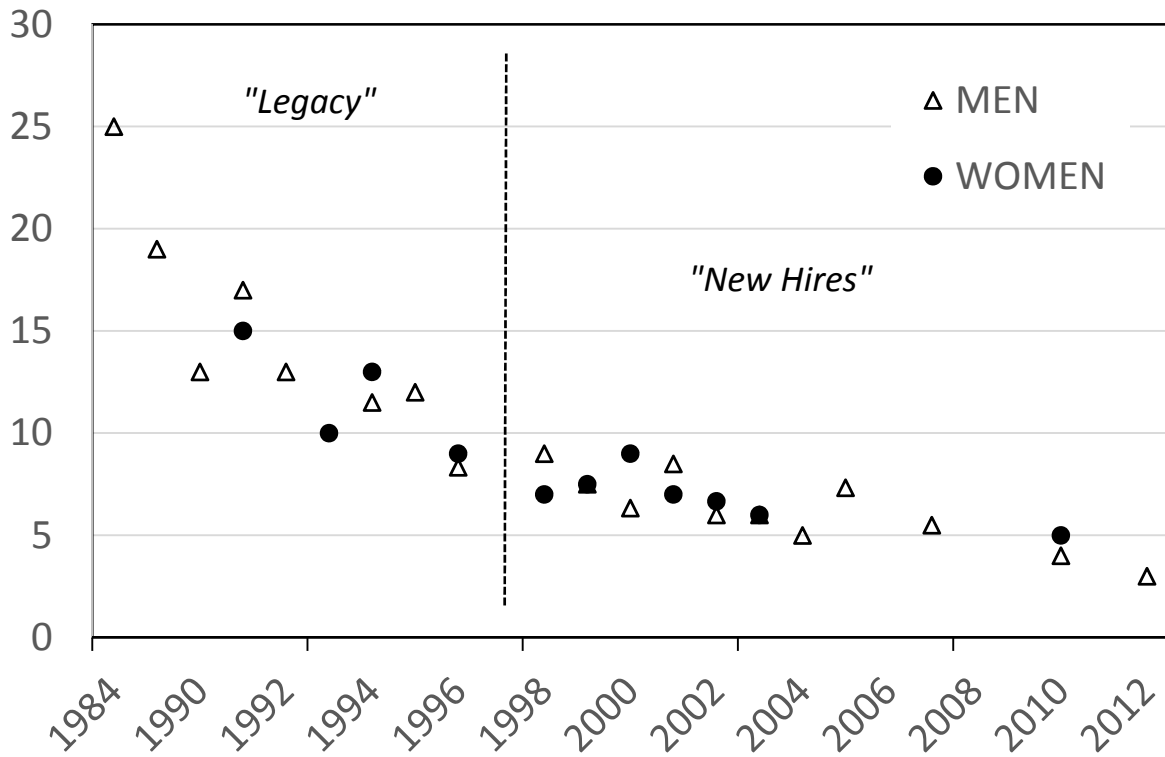


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