The Effectiveness of Institutional Intervention at Minimizing Demographic Inertia and Improving the Representation of Women Faculty in Higher Education

Amanda V. Bakian
Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/gradreports

Part of the Statistics and Probability Commons

Recommended Citation
Bakian, Amanda V., "The Effectiveness of Institutional Intervention at Minimizing Demographic Inertia and Improving the Representation of Women Faculty in Higher Education" (2009). All Graduate Plan B and other Reports. 1282.
https://digitalcommons.usu.edu/gradreports/1282
THE EFFECTIVENESS OF INSTITUTIONAL INTERVENTION AT MINIMIZING DEMOGRAPHIC INERTIA AND IMPROVING THE REPRESENTATION OF WOMEN FACULTY IN HIGHER EDUCATION

by

Amanda V. Bakian

A report submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Statistics

UTAH STATE UNIVERSITY
Logan, Utah

2009
ABSTRACT

The effectiveness of institutional intervention on minimizing demographic inertia and improving the representation of women faculty in higher education

by

Amanda V. Bakian

Across all science and engineering disciplines, women currently receive 46% of the doctoral degrees granted annually. Despite gains in doctoral degrees earned by women over the past 30 years, they remain under-represented among full time tenured/tenure-track science and engineering faculty compared to their presence among degree recipients. The inequality gap is widest among full professors at 4 year research universities where women account for a mere 16% of all S&E full time full professors. Multiple hypothesis have been proposed to account for women’s under-representation relative to men including those based on human capital/economic theory, feminist theory, innate biological gender differences, and demographic inertia. This study is concerned with the role demographic inertia plays in limiting women’s representation among full time tenured/tenure-track faculty at the ranks of assistant, associate and full professor. Specifically, we investigate the efficacy of an intervention program at increasing the representation of women S&E faculty at a research university identified as “Snow State University”. We formulated six matrix population models, three male and three female specific models, using vital parameters configured from data collected prior to and during the institutional intervention program. The models indicate that demographic inertia creates barriers limiting women’s representation at Snow State University but that the
intervention program has begun to break down these barriers. Specifically, a number of women specific demographic rates show improvement during intervention including increased recruitment of assistant women faculty, increased promotion of associate women faculty and improved retention of assistant women professors. The representation of women in the ranks of assistant and associate professor is projected to reach parity with men within 30 years if the intervention is continued. This projection is optimistically based on the assumption of continued positive growth in total faculty population. We conclude our study by making a number of recommendations of ways to increase women faculty’s representation in the face of demographic inertia.
ACKNOWLEDGEMENTS

Funding for this project was provided by the National Science Foundation ADVANCE grant to Utah State University, NSF Grant: SBE 0244922. I would like to thank my MS statistics committee, Drs. Richard Cutler, Kimberly Sullivan and Mevin Hooten for their guidance and assistance in this project’s preparation. Trish Kalbas-Schmidt’s help with data collection and data checking was essential, and I am thankful for the access to HR files and data provided by USU’s human resource department. Many thanks to the USU ADVANCE team for inviting me to conduct this research project. I am grateful to my parents, Linda and Victor, and sister, Marielle, for their endless support and encouragement. Finally, I would like to acknowledge friends for their support and specifically Ian McAlexander, Emily Sullivan, Brent Mitchell and Suzanne Lewis for providing useful comments and suggestions in preparation for my project defense.
Introduction

Over the past 40 years, the number of women earning doctoral degrees in Science and Engineering (S&E) fields in the United States has grown steadily with the most recent set of national statistics indicating that approximately 38% of all S&E doctoral degrees were awarded to women in 2005. Given that a mere 8% of S&E doctoral degrees were granted to women in 1966, the increase in the number of women obtaining S&E doctorates today is impressive. The proportion of doctoral degrees earned by women varies among disciplines. In engineering where female graduate students are scarcest, women received 18% of doctoral degrees in 2005. In comparison, since mid-1990 women have earned the majority of doctoral degrees in sociology and psychology; parity was recently reached in the proportion of doctorates awarded to men and women in the life sciences (National Science Foundation [NSF], 2007).

Women’s increased representation among S&E doctoral recipients would be expected to be matched by their increased availability in the S&E employment pool. In reality, women remain under-represented in professional S&E positions (Long, 2001). This discrepancy is especially prevalent among academic tenured/tenure-track faculty; at four year U.S. universities and colleges, women account for 19%, 34% and 42% of full, associate and assistant S&E faculty (National Science Board [NSB], 2008). Women’s overall representation among academic job holders has increased over the past 30 years however much of this growth has occurred in their procurement of part time/non-tenure-track academic positions where women are more likely to be employed than men (Cataldi, Bradburn, and Fahimi, 2005). Among full-time/tenure track academic faculty,
women remain underrepresented relative to their availability in the job pool market (Bradburn and Sikora, 2002; Long, 2001; Nettles, Perna and Bradburn, 2000; West and Curtis, 2006). For example, although women have earned the majority of sociology doctorates since mid-1990, they comprise only 38.5% of sociology faculty in the top 50 nationally ranked sociology departments (Beutel and Nelson, 2006). Among research universities the following disconcerting trend has developed: the number of tenured/tenure-track women faculty decreases, in general, with increasing university prestige, Carnegie classification and faculty rank, and the more prestigious the institution the less likely a full professor is to be a woman (Bradburn and Sikora, 2002; Cataldi, Fahimi and Bradburn, 2005; West and Curtis, 2006).

The underemployment of professional S&E women translates into a loss of talent, skills, and leadership essential to the continued growth of the U.S.’s science and engineering sectors (Handelsman et al., 2005; Preston, 2004; West and Curtis, 2006; Wickware, 1997). University and national level programs such as the National Science Foundation’s ADVANCE program aimed at promoting women scientists are elucidating the various forces responsible for shaping the gender composition of our university faculty. Four broad hypotheses have been proposed to explain the scarcity of full time tenured/tenure-track S&E women faculty members including those based on human capital/economic theory, feminist theory, innate biological gender differences, and demographic inertia (Marschke, 2004; National Academy of Sciences [NAS], 2006).

Our study tests the influence of demographic inertia on occupational segregation in a university setting. We believe that demographic inertia, the long-term combined consequences of demographic forces on minority group representation in an occupational
setting (Feinberg, 1984; Hargens and Long, 2002), has played not only a major role in limiting women’s current representation among academic faculty but will continue to limit their representation into the foreseeable future. Our study investigates the efficacy, given demographic inertia, of the National Science Foundation’s ADVANCE program, an intervention strategy, on promoting and retaining S&E women faculty at a research university. Since demographic inertia is expected to continue to impede the advancement of faculty women, we are interested in exploring the potential effect of intervention strategies such as ADVANCE on minimizing demographic inertia’s impact. To do so, we examined the influence of demographic rates including new hire, retention, promotion and attrition rates on projected sex ratios of full time tenured/tenure-track women and men faculty at a high research activity Carnegie classified university under various scenarios: (1) with the ADVANCE intervention program, (2) without the ADVANCE intervention program and (3) initially with the ADVANCE intervention program for 5 years followed by a return to the demographic rates experienced prior to ADVANCE.

The Hypotheses

Human capital is the accumulation of specialized skills, experiences and qualifications gained by an individual in his or her preparation for entering the job market (Becker, 1964). In the context of gender workplace segregation, human capital theory proposes that men and women develop dissimilar sets of skills and abilities setting them on distinct career paths. Women are expected to master skills and abilities that enable them to obtain jobs flexible enough to allow for both child/family care and career development (Mincer and Polachek, 1974). Therefore, according to human capital theory, women are underrepresented in full time tenure-track academic positions because
the employment skills they acquire promote family and career balance but are not the type of capital required for successful navigation of an academic career (Johnson and Stafford, 1974). An alternative hypothesis based on human capital theory posits that women and men may attempt to develop identical job market skill sets; however family care giving disruptions during women’s career training reduces their human capital. After failing to develop the required set of tools and skills, women are unable to compete with men for full time, tenure/tenure-track academic positions (NSF, 2003).

Overt discrimination towards women in the workplace by employers is costly, and according to human capital theory, market forces are expected to expel sex based discriminatory hiring practices over the long term (Ferree and McQuillan, 1998). Employers with excess resources can, however, overtly discriminate against women because they are able to afford the cost of discriminating (Tolbert and Oberfield, 1991). Preferential male hiring practices, as opposed to overt discrimination, evolve when employers view women as less reliable and more costly employees due to their family and care giving responsibilities. When employers assume that hiring women comes with costs, they develop preferential hiring practices that result in a male dominated work force.

A feminist theory of gender inequality and occupational segregation proposes that existing institutional factors create a work environment beneficial to men but hostile to women (NAS, 2006; Padavic and Reskin, 2002; Powell, 2007; Wilson, 2004). In the academic setting, potential factors responsible for inducing a chilly climate for women include inflexible tenure clocks and tenure requirements that punish them, tokenism of women faculty members leading to strong feelings of isolation (Etzkowitz, Kemelgor and
Uzzi, 2000; Kanter, 1977; Tolbert, Simons, Andrews and Rhee, 1995), limitations on collaboration or networking opportunities for women faculty members (Etzkowitz, Kemelgor, Neuschatz and Uzzi, 1994; Macfarlane and Luzzadder-Beach, 1998), lack of access to effective mentors (Holmes and O’Connell, 2007; Preston, 2004; Wilson, 2004), higher work expectations for women than men (Long, Allison and McGinnis, 1993; Wells, 2003), lack of access to affordable childcare (Holmes and O’Connell, 2007) and the use of gender-biased evaluations (Handelsman et al., 2005; Valian, 1998). These factors in combination produce a toxic work environment that is believed to discourage women from actively seeking full time employment at research universities (NAS, 2006).

Feminist theory posits that instead women may preferentially seek out employment in environments they perceive as healthier and more flexible than the one offered by the academe (Valian, 1998).

In addition to the inhospitable academic climate, feminist theory also considers gender schemas and accumulated disadvantages as factors limiting women’s representation in higher education. A gender schema is the combined set of characteristics, traits and behaviors that an observer expects individuals to exhibit based on their sex (Bem, 1981). The formulation of gender schemas is a by-product of socialization beginning at a young age. Gender schemas influence how members of society treat women as scientists and engineers (Valian, 1998). Bias, both conscious and unconscious, occurs when an individual forces his or her preconceived notion of acceptable behavior on to others. Feminist theory proposes that gender bias originating through gender schemas results in women accumulating small disadvantages that over the course of their careers impose considerable limitations on their attainable level of success.
Faculty women experience their first disadvantage at the onset of their S&E careers when they are perceived by their peers and superiors to have lower status than their male colleagues. This forces them to perform throughout their academic careers at levels higher than what is expected of men (Etzkowitz et al., 2000). Over time, women’s accumulation of disadvantages can alter their career trajectories by reducing their promotion rates and increasing both their time spent in rank and their non-retirement attrition rates. Women’s lower promotion rates and higher attrition rates relative to men’s, due to accumulated disadvantages, likely contributes to the current paucity of associate and full women professors (Valian, 1998).

Inherent differences in science aptitude between men and women are also hypothesized to be responsible for gender discrepancies in the sciences and engineering (Browne, 2002; Browne, 2005; Fogg, 2005, Kimura, 2002; National Research Council [NRC], 1989). Current research suggests that differences in aptitude observed between men and women in science are largely relics of socialization and contextual factors (Hyde, 2005; Xie and Shauman, 2003). Since the early 1970’s, women’s overall proficiency in scientific fields including mathematics has increased over time while men’s aptitude has remained fairly constant (Hyde, 2005; Hyde, Fennema and. Lamon, 1990). The reduction in the science and mathematics proficiency gap between men and women is strong evidence against the biological and physiological gender differences hypothesis (Hyde, 2005).

Demographic inertia

Demographic forces influencing the gender composition of a university’s faculty population include the recruitment rate of new faculty (new hire rate), non-retirement
faculty attrition rates, faculty promotion rates, and faculty retirement rates. The combination of these factors is hypothesized to exert strong control over the pace at which a university's faculty gender composition can change (Hargens and Long, 2002; Marschke, Laursen, Nielsen and Rankin, 2007). Despite the availability of qualified women in the employment pool, the combination of the aforementioned demographic parameters can produce demographic inertia in which faculty turnover occurs at such a slow pace that maintenance of the unbalanced, male dominated status quo occurs over the long run.

Parity in the representation of faculty men and women may be seriously challenged by the forces of demographic inertia, and we propose that quantifying its influence should be the starting place for any study of occupational segregation. After quantifying the effects of demographic inertia on faculty segregation and observing unaccounted for inequality, alternative hypotheses should be examined including human capital, chilly climate and accumulated disadvantages, or innate biological gender difference hypotheses. Kulis, Sicotte, and Collins (2002) followed a similar approach in which they first attempted to explain women faculty member's under-representation using labor market forces. After failing to fully explain the variance in women's under-representation from a labor market perspective, they tested the influence of other factors including employment demand for women outside academia, competition from foreign born scholars and gender based differences in training and education.

Only a few other studies have examined the role of demographic inertia on occupational segregation (e.g. Alpert, 1989, Hargens and Long, 2002, Marschke et al., 2007). Feinberg (1984) examined the influence of demographic inertia and the
effectiveness of affirmative action programs on the membership of minority employees at
the Gramercy metals plant. Using simple deterministic models, Feinberg varied the new
hire and attrition proportions of black and white employees and projected the length of
time required to meet specific affirmative action goals. Efforts at promoting equal
representation of black and white metal craftsmen were found to be limited by
demographic inertia; models projected estimates of 31 to 85 years to reach racial parity as
a result of the time lag induced by demographic inertia. Despite the availability of
minorities in the employment pool, low new hire rates were identified as the major
limiting factor responsible for preventing racial parity within a reasonable time frame.

Both Hargens and Long (2002) and Marschke et al. (2007) investigated
demographic inertia in the context of women’s under-representation among academic
faculty. Cohort-component models were employed by Hargens and Long (2002) to
project the time to reach parity for men and women sociology faculty members under
different starting scenarios. By varying the initial age-sex structures of faculty, the rate of
faculty new hires, and the gender composition of the employment pool, they found that
demographic factors alone can delay reaching equality in the number of total faculty
women relative to their availability in the job pool by approximately 35 years. Their
analysis identified the availability of women in the employment pool, departmental age
structure, faculty attrition rate and faculty new hire rate as the parameters exerting the
greatest influence on the rate of faculty change.

Some universities attempt to compensate for tenured/tenure-track women faculty
member’s under-representation by setting target goals for new hires or executing other
initiatives aimed at promoting parity. Marschke et al. (2007) used differential equation
models to test demographic inertia and the effectiveness of five intervention programs on promoting parity among men and women faculty members at a large research extensive university they titled “Mountain University”. Their analysis demonstrated the strong control demographic inertia has on gender integration and found that if recent demographic patterns at Mountain University persist without administrative intervention, it will take over 40 years for women to comprise 34% of all campus faculty members. Intervention strategies required by Mountain University to produce a faculty pool that matches the gender composition of the job applicant pool involves the equal (50/50) hiring, promotion and attrition of women and men.

Model and Objectives

We use a matrix population modeling approach to model demographic inertia based on actual university data that builds upon the modeling efforts of Hargens and Long (2002) and Marschke et al. (2007). Matrix population models are a rigorous, straightforward approach to projecting population growth and change (Caswell, 2001; Keyfitz and Caswell, 2005). Perturbation analysis of matrix models reveals the influence of individual model parameters on population growth, and the potential effects of varying vital parameters on population change (Caswell, 2001). While Marschke et al. (2007) varied demographic rates to reflect hypothetical university intervention strategies, our approach uses results from sensitivity and elasticity analyses to inform us of both the actual and potential effectiveness of institutional intervention strategies including the NSF’s ADVANCE program.

Our models build upon earlier demographic inertia models in a number of ways. First, we classify faculty by faculty rank rather than by age. Although there is a
relationship between faculty rank and age, considerable variance exists in this relationship, and we feel that faculty classification based on rank is more accurate than classification based on faculty age. Our models also assume a growing, rather than static, faculty population size. Despite concurrent increases in the number of part-time and non-tenure-track faculty members, the total number of full time faculty positions in the US has grown over the past century, and given the anticipated retirement of baby boomers, the number of new hires is expected to increase (Lehming, 1998). Therefore, while most previous studies of demographic inertia have assumed stationary population sizes we included population growth in our models because we feel the assumption is relevant in a university. Finally, our models include recruitment of new faculty at the ranks of associate and full professors. Although the majority of new hires enter as assistant professors, faculty recruitment of associate and full professors is not uncommon and has implications on women faculty’s representation and advancement. The hiring of faculty at academic ranks other than assistant professor has been previously overlooked by studies of demographic inertia.

The objectives of our models are: (1). Do the demographic rates between men and women differ, and what is the impact of ADVANCE on women and men’s new hire, promotion, retention, and attrition rates? (2). How do the pre-ADVANCE vs. ADVANCE demographic rates impact demographic inertia’s effect on women’s projected representation? (3) How long will it take for the sex ratios of women to men full time tenured/tenure-track faculty to reach 30%, the proportion of SSU’s S&E job applicant pool comprised of women, and 50% at the ranks of assistant, associate and full professor as a function of varying demographic rates? (4) What demographic parameters
should be the focus of future institutional level interventions as indicted by the models’ results and the perturbation analysis?

Methods

Data and transition tables

The demographic career activity of “Snow State University’s” (SSU) science and engineering tenured/tenure-track faculty employed during all or part of 1998-2007 was used for estimation of vital parameters. Snow State University is a four year public, high research activity (Carnegie Classification) university located in the western US with a current student body enrollment of approximately 23,000 undergraduate and graduate students. The nineteen science and engineering departments at Snow State University are organized into four colleges and cover the disciplines of mathematics and statistics, life sciences, agricultural sciences, natural resources, economics and engineering. Psychology and most of the social sciences are not included among SSU’s science and engineering fields. During the fall semester of 2007, SSU employed 319 tenured/tenure track faculty in these four colleges, 52 women and 267 men, in three faculty ranks: 149 full professors, 89 associate professors and 81 assistant professors.

From 2003-2009, Snow State University participated in the National Science Foundation’s ADVANCE program, aimed at promoting and retaining professional women scientists and engineers through institutional transformation. As an ADVANCE participate, SSU implemented programs to increase the transparency of the tenure-track promotion system, improve departmental work climates, improve faculty recruitment practices, assist in dual career accommodation, advance collaborative research
opportunities and improve campus childcare options. The database used in our study spans 10 years and includes five years of data representing faculty demography prior to SSU’s participation in the ADVANCE program and five years of data covering the period of SSU’s ADVANCE participation. Separate matrix models formulated with data representing both pre-ADVANCE and ADVANCE periods were analyzed in this study as a means of investigating the effectiveness of SSU’s ADVANCE program.

New hire, promotion, retirement and non-retirement attrition events occurring during this 10 year period were recorded (see Table 1 for new hire and attrition counts). Men and women were treated as separate populations with distinct matrix model parameters used in model formulation. Matrix models were stage classified by faculty rank: assistant professor, associate professor, full professor or exit. The projection matrices use the three employment stages: assistant professor, associate professor, and full professor while the transition matrices also include the fourth stage, exit. We did not distinguish between exit strategies in our model hence retirement and non-retirement attrition exits were grouped together into a single exit category. Individuals were counted in the exit stage the year following his or her last year of tenure/tenure-track faculty employment at SSU. The demographic data was converted into transition table format, \( M_{it} \), where \( i = \text{male/female} \) and \( t = 1998, 1999, \ldots, 2007 \). From these transition tables, model parameters were estimated for constructing 9 annual projection matrices for men and 9 annual projection matrices for women. Three different mean matrices were formulated from the nine annual projection matrices: (1) a mean matrix containing vital parameters averaged from all years of data, 1998-2007, “all years” (2) a mean matrix containing parameters averaged from the pre-ADVANCE program years (1998-2002),
"pre-ADVANCE", (3) a mean matrix containing parameters averaged from the ADVANCE program years (2003-2007), “ADVANCE”.

The Deterministic model

A total of six stage classified mean matrix models, 3 male and 3 female based models, were formulated for projecting future changes in the gender composition of SSU’s science and engineering faculty. The matrix models took the following form:

\[ n(t + 1) = An(t) \]  \hspace{1cm} (1)

where \( n \) is a vector of stage abundances and \( A \) is a deterministic projection matrix. An annual time step was used for projecting the models and original vital rates were estimated for demographic transitions occurring within an academic year. Faculty demography was examined for a ten year period, from 1998-2007, covering nine academic years. A total of 18 annual projection matrices, nine for women and nine for men were formulated. Vital rates included in the three final projection matrices represented mean projection matrices: All years (1998-2007), pre-ADVANCE (1998-2002) and ADVANCE (2003-2007) as described above.
Figure 1. The employment cycle for tenured/tenure-track science and engineering faculty at Snow State University. The circles indicate faculty rank stages, and the arrows represent feasible transitions: Distribution of new hires to faculty ranks ($G_i$), rank retention probabilities ($S_i$), promotion probabilities ($P_i$) and new hire recruitment probabilities ($H_i$). The new hire stage is a temporary holding stage where new hires are placed at time $t$ before their distribution into faculty positions at time $t+1$.

The projection matrices were stage classified with four classes; new hires (new hires entering the model at the start of the academic year), assistant professors, associate professors and full professors. The employment (equivalent to a life cycle graph) cycle diagram (presented in Figure 1) illustrates the possible employment transitions for a tenured/tenure-track science and engineering professor at SSU; the employment cycle is described by the following vital parameters:
The $H_i$ entries in the projection matrix are the recruitment rates, the $S_i$ entries on the diagonal are the retention probabilities or the probability of remaining in the same faculty rank, the $P_i$ entries are the promotion probabilities or the probability of getting promoted from assistant to associate professor or associate to full professor, and the $G_i$ entries are the new hire distribution rates or the probability of hiring at the assistant, associate or full professor ranks. The new hire stage is a temporary placeholder position where faculty hired at the end of an academic year are dispersed among the three faculty ranks at the beginning of the next academic year according to $G_i$.

Parameter estimation

Maximum likelihood estimates of the retention ($S_i$), promotion ($P_i$) and attrition ($M_i$) probabilities were calculated as:

$$\hat{a}_{ij} = \frac{m_{ij}}{\Sigma_h m_{hj}}$$

(Caswell, 2001), where $m_{ij}$ is the number of faculty starting the academic year in rank $j$ and ending the academic year in rank $i$, and $\Sigma_h m_{hj}$ is the total number of faculty in rank $j$ at the start of the academic year.
The annual $G_i$ rates were estimated as a function of the proportion of new male and female faculty hired in each faculty rank at the end of an academic year given by:

$$\hat{G}_i = \frac{m_j}{N}$$

(4)

where $m_j$ is the number of new faculty hired in rank $j$ and $N$ is the total number of new hires for a given year, this value is equivalent to $h_i$ in the new hire (recruitment) rate function described below. This approach assumes that the number of new hires distributed into rank $j$ in year $t+1$ is determined in year $t$ when the $t+1$ new hire cohort is added to the population vector $n_i$ in the new hire “place holding” stage. At the $t+1$ time step, the new hire population at step $t$ is distributed among the three faculty rank stages according to $G_i$.

We chose to model recruitment rate, $H_i$, in a manner akin to “anonymous” reproduction in ecological population studies (e.g. Caswell, 2001; Ripley and Caswell, 2006). Here, the number of new hires at each time step is a function of the proportional sizes of each faculty stage. For our model,

$$n_{1}(t + 1) = \sum_{i} H_i n_i(t)$$

(5)

so the new hire population, $n_{1}$, at time $t+1$ is related to the size of the total faculty population through $H_i$, the new hire rate, which varies by rank. Since university faculty hiring practices are likely influenced by total faculty population size as well as the
number of faculty members in each rank, \( H_i \), is related to both the average number of new faculty hires as well as the relative sizes of the faculty population at each rank:

\[
H_i = \overline{H} h_i \quad \text{where} \quad \sum_i h_i = 1 \quad \text{and} \quad \overline{H} = \frac{n_1(t + 1)}{\sum_i h_i N_i(t)}
\]

(6)

In this form, \( \overline{H} \) relates the total number of new hires to both the number of new hires at each rank and the total size of the faculty at each rank at time \( t \). By modeling new hire rate in this fashion, there is no upper limit on faculty population growth. We feel that this assumption is justified given both SSU's continuous student and faculty growth since its founding.

The projection matrix, \( A_{it} \), was amended to formulate a transition matrix, \( P_{it} \), by including an absorption row and column that accounts for, in the \( M_i \) entries, retirement and non-retirement attrition in the population (Caswell, 2001):

\[
P_{it} = \begin{pmatrix}
0 & H_1 & H_2 & H_3 & 0 \\
G_1 & S_1 & 0 & 0 & 0 \\
G_2 & P_1 & S_2 & 0 & 0 \\
G_3 & 0 & P_2 & S_3 & 0 \\
0 & M_1 & M_2 & M_3 & 1
\end{pmatrix}
\]

(7)

\( i = \text{men, women}; \ t = \text{"All years", pre-ADVANCE, ADVANCE} \)

The fundamental matrix model allows us to treat the employment cycle of an individual at SSU as a Markov chain. Mean stage class duration estimates were found through the analysis of the transition matrices.
Population projection

The projection matrices were each projected for 30 time steps to investigate population growth and change. Specifically, we projected the women to men sex ratio over thirty years to determine the length of time required for women assistant, associate and full professor’s representation to match both their availability in the job market pool and exact (50/50) parity with men. Our estimate of women’s availability in the S&E job market pool was based on the percentage of total S&E doctoral degrees granted to women according to the most recent set of national statistics (NSF, 2007, table F-12). The National Science Foundation reports the percentage of doctoral degrees earned by women as broken down by discipline; we only included the fields considered S&E at SSU and found the average percent of doctoral degrees earned by women across these disciplines.

The final set of projections investigated the consequence of reverting back to pre-ADVANCE demographic conditions following an initial projection using the ADVANCE model. In this exercise, the male and female populations were first projected for 5 years using the ADVANCE model. The population vector at the end of five years was then projected for an additional 25 years using the pre-ADVANCE model and the sex ratios of women/men at each faculty rank over the entire 30 year projection periods was found.

Population Parameters
Our stage-classified matrix model presented in equation (1) can take the form of the characteristic equation:

\[
\det(A - \lambda I) = 0
\]  

(Caswell, 2001). Solving the characteristic equation yields a set of eigenvalues, \( \lambda_i \), the number of eigenvalues corresponds to the dimensions of the square matrix. The largest eigenvalue in magnitude, \( \lambda_1 \) or the population growth rate, directs the long-term behavior of \( n(t) \). The analytical solution to the characteristic equation also yields the dominant right eigenvectors, \( w_i \), which describe the stable population structure of \( n(t) \).

The expected amount of time an individual in rank \( j \) at time 0 spends in each rank prior to exiting SSU is described by the fundamental matrix \( N \). The fundamental matrix is found by treating the transition matrices as absorbing Markov chains (Caswell, 2001, chapter 5). The fundamental matrix also provides the mean and variance of the time spent in rank at SSU.

**Statistical inference**

Meaningful between matrix comparisons of vital and population level parameters requires a measurement of uncertainty associated with the model and population-level parameter estimates. Confidence intervals and standard errors were estimated via bootstrap resampling (Efron and Tibshirani, 1993). The bootstrap resampling method was applied to find confidence intervals and standard errors for the population level parameter \( \lambda_1 \), and all lower vital parameters, \( H_i, S_i, G_i, \) and \( P_i \). Estimation of the \( S_i, M_i \) and \( P_i \) vital parameters along with their associated confidence intervals and standard
errors required resampling with replacement of the original transition table data with resampling size equal to the faculty population size $N_i$ where $i =$ men, women and $t = 1998, 1999, ... , 2007$. Bootstrap estimates of new hire recruitment, $H_i$, and new hire distribution, $G_i$, rates involved the resampling with replacement of their lower level parameters $m_i$, $h_i$, and $H_i$ where the resampling size was 10, the number of total data collection years. The resampling scheme was repeated 2000 times for each bootstrap sample and from each bootstrap sample a calculation of the original estimator was made. The empirical distribution of the bootstrap estimates was used for finding the mean and standard errors of each vital parameter, $\alpha_{ij}$. Population growth rate, $\lambda_i$, standard errors were estimated by reshuffling and bootstrapping the original annual projection matrix vital rates. Since we could not assume that our bootstrap samples come from a normal distribution, 95% confidence intervals were computed as percentiles of the empirical bootstrap distribution.

**Sensitivities and elasticities**

Perturbation analysis was conducted to investigate the individual-level influence of the vital rates on the population growth rates of the six projection matrices. Specifically, we examined the sensitivity and elasticity of $\lambda_i$ to the demographic vital parameters: new hire rate, retention probabilities, and promotion probabilities. Sensitivity matrices:
\[ S = \left( \frac{\partial \lambda}{\partial a_{ij}} \right) \]  

(Caswell, 2001, pg. 210) were calculated where each entry in the matrix described the absolute response of population growth rate to a change in matrix entry \( a_{ij} \) keeping all other vital parameters constant.

When vital parameters are measured on multiple scales, an elasticity analysis, which measures the response of \( \lambda \) to proportional changes rather than absolute changes in vital rates, proves informative. The elasticity matrix showing the proportional response of the population growth rate to proportional changes in matrix entries, \( a_{ij} \) is:

\[ E = \left( \frac{a_{ij}}{\lambda} \right) \left( \frac{\partial \lambda}{\partial a_{ij}} \right) \]  

(Caswell, 2001, pg. 227)

**Stochastic model**

The vital parameter values in the 18 original annual transition matrices vary between years. Annual variation in vital parameters occurs when environmental conditions influencing population level demographics also vary. In a university setting, environmental factors influencing hiring, promotion and retention practices should be expected to differ annually. We were interested in exploring the impact of this environmental stochasticity on faculty demographic inertia.
Nine annual projection matrices describe the transition probabilities for tenured/tenure-track faculty in a given year. When each annual projection matrix is treated as a single, discrete environmental state than a sequence of these annual projection matrices forms a realization of a stochastic environment (Caswell, 2001; Morris and Doak, 2002). We used these nine annual projection matrices to conduct a stochastic simulation for projecting population change under the assumption of environmental stochasticity. We generated a sequence of 10,000 matrix samples selecting one of the nine projection matrices at each sampling. At each time step, a projection matrix was reconstituted and each realization was projected for 30 time steps. Realizations produced estimates of final faculty population sizes in each rank. The Stochastic log growth rate, log $\lambda_s$, for the stochastic simulation was estimated using Tuljapurkar’s approximation (Tuljapurkar, 1990) where:

$$\log \lambda_s \approx \log \lambda_1 - \frac{\text{Var}(\log \lambda_1)}{2\lambda_2}$$  \hspace{1cm} (11)$$

Stochastic log growth rate was also estimated directly from simulation by computing the arithmetic mean of $\log \left[ \frac{N(t+1)}{N(t)} \right]$ between successive years and 95% confidence intervals were estimated directly from the distribution of the stochastic log growth rate (Morris and Doak, 2002). Finally, the sensitivity of log $\lambda_s$ and elasticity of $\lambda_s$ was computed (see Caswell, 2001, pgs 405-407).

Results
The three paired men and women’s mean projection matrices: “all years”, “pre-ADVANCE” and “ADVANCE”, are displayed in Table 2. Promotion probabilities (P_i) and the probabilities of hiring at the rank of associate or full professor (G_i) are generally higher for men than women. Women show higher promotion probabilities under the ADVANCE scenario than either the pre-ADVANCE or “all years” scenarios. The opposite trend is observed among the men’s projection matrices; men show higher promotion probabilities in the pre-ADVANCE and ADVANCE projection matrices. A high probability of hiring at the assistant professor rank exists for both men and women in all three projection matrices. Men show small probabilities of hiring at the rank of associate and full professor while women have almost negligible probabilities of being hired at ranks other than assistant professor. Both men and women have fairly high retention probabilities (S_i) at all faculty ranks.

The transition matrices also presented in Table 2 differ from the projection matrices in their addition of an exit row and column providing the attrition probabilities (M_i) of male and female faculty at each faculty rank. In the pre-ADVANCE transition matrices, female assistant professors have higher probabilities of exiting USU and lower probabilities of promotion than male assistant professors while men show a higher probability of attrition at the associate and full professor ranks than their female colleagues. The ADVANCE transition matrix shows a decrease in attrition for female assistant faculty but an increase in attrition for women full professors compared to the pre-ADVANCE transition matrix. It should be noted however that for the women full professors, all but one of these attrition events was due to retirement. In the ADVANCE
transition matrix, male attrition probabilities of assistant, associate and full professors show increases from their pre-ADVANCE matrix values.

The population growth rate, $\lambda_1$, and 95% confidence intervals of the six deterministic projection matrices and the log stochastic growth rate and 95% confidence intervals of the stochastic simulation are shown in Figure 2. All three mean projection matrices as well as the stochastic simulation predict higher population growth rates for women than men. The largest and smallest differences in magnitude between men and women’s estimated population growth rates are observed in the ADVANCE and pre-ADVANCE matrices respectively.

Distinct population structures exist in the male and female S&E faculty populations at USU from 1998-2007 (see Figure 3). Presently, the majority of women are assistant professors with fewer numbers of associate and full women professors while the bulk of men are full professors with fewer associate and assistant professors. The total size of the male faculty population varied little from 1998-2007; the male population grew from 266 in 1998 to 271 in 2007. The total population of women tenured/tenure-track professors grew consistently during the same period starting at 36 in 1998 and increasing to 51 by 2007.

The projection matrices project continuation of the faculty population structure status quo for both men and women as illustrated in the “all years” projection matrix stable stage distribution shown in Figure 4. Although the projection matrices project continued growth in the size of the female faculty population, this growth is projected to have little impact on how the population is distributed. Most of the growth in the female faculty population is projected at the assistant faculty rank accompanied by slower
growth in the ranks of associate and full women professors. Slow future population
growth of male faculty is not projected to impact the male population’s faculty rank
distribution.

In comparison, the ratio of women to men tenured/tenure-track faculty is
projected to increase over the course of 30 years due to increases in total faculty
population size and higher population growth rates for women than men (shown in
Figures 5a, b and c). The rate of change in the ratio of women/men varies by rank and
parameterization values of the projection matrix. We estimated the availability of women
in the S&E faculty job applicant pool at 30% based on the most recent set of national
statistics (NSF, 2007) and investigated the number of years necessary for the ratio of
women/men faculty to match women’s availability in the job market pool. Also, we
determined the number of years required for the population sizes of women and men
assistant, associate and full faculty to reach exact parity. The “all years” matrix predicts
lags of 5, 1, and 13 years before the ratio of female to male new hire, assistant and
associate faculty matches their availability in the job pool; the ratio of female to male full
professors, as projected by the “all years” matrices, is not projected to reach 30% women
within 30 years. The “all years” matrices project a lag of 19, 17 and 28 years before men
and women are represented in parity as new hires, assistant professors and associate
professors respectively. Under “all years” matrix parameterization, the number of female
full professors is not projected to match the number of male full professors within the
next 30 years.

The representation of women fares the worst in the pre-ADVANCE matrix
projections which projects 17, 11, and 19 years for the number of female new hires,
assistant and associate professors to match their availability in the employment pool. The pre-ADVANCE projection matrices do not project the ratio of female full professors to reach 30% within 30 years. Women’s projected representation is most optimistic under the parameterization of the ADVANCE projection matrix. Under this scenario, the ratios of women/men new hires, assistant and associate professors are predicted to match job market availability within 3, 1 and 11 years respectively. Again, the ratio of full female/male professors is not projected to reach 30% within 30 years even under the ADVANCE parameterization scenario. Based on the ADVANCE matrix projections, parity between men and women new hires, assistant professors and associate professors is predicted in 13, 13 and 22 years respectively.

The “mixed model” where male and female populations were first projected by the ADVANCE model for 5 years and then projected for an additional 25 years by the pre-ADVANCE model projects the proportion of women assistant, associate and total professors to reach 30% representation in 1, 12 and 19 years respectively (see Figure 5d). The representation of women full professors is not projected to reach 30% by the “mixed model” exercise, and exact parity between men and women is only projected for the assistant professor population in 21 years.

The stochastic simulation produced 10,000 thirty year projected estimates of male and female assistant, associate and full population sizes. The female/male ratios derived from the stochastic population projections are shown in Figure 6. The stochastic simulation projects that at the end of 30 years, 60% of assistant and 44% of associate professors are women. The stochastic simulations also project that only 11% of full professors will be women at the end of 30 years.
The sensitivities of the population growth rate to the “all years” mean matrix vital parameters are shown in Figure 7. The perturbation analysis shows that women and men’s population growth rates respond differently to changes in the various matrix vital parameters. Changes in assistant professor survival probabilities and assistant and associate new hire probabilities will impact women’s population growth rate. Men’s population growth rate is sensitive to changes in the promotion of both assistant and associate faculty, and to the survival probabilities, especially of assistant and full professors. The population growth rates of men and women respond to changes in the probability of hiring assistant professors more than to changes in the probabilities of hiring faculty at the associate or full faculty ranks. The recruitment rate parameters \( (H_i) \) contribute to both men and women’s population growth rates: women’s population growth rate is most sensitive to recruitment of assistant professors followed by recruitment of associate professors while men’s population growth rate is most sensitive to recruitment of full faculty followed by recruitment of associate and assistant professors.

The mean stage durations of male and female faculty estimated from the three sets of projection matrices are shown in Figures 8a, b and c. Under all three parameterization scenarios, women experience longer rank durations than their male colleagues with the exception of full professor duration. The “all years” mean matrix projects that women spend, on average, 6.8 years as assistant professors, 14.5 years as associate professors and 12.8 years as full professors. Men, on the other hand, are projected to spend 5.45 years as assistant professors, 4.7 years as associate professors and 8 years as full professors. Surprisingly, women are projected to spend 8.25 years as assistant professors under the
ADVANCE scenario, but only 6 years as assistant professors under the pre-ADVANCE scenario. The amount of time men spend in the assistant professor positions varies only slightly among the three projection scenarios.

Discussion

Our study shows that short term intervention strategies such as ADVANCE are effective at minimizing demographic inertia’s impact on women’s representation among university faculty. The actual reversing of demographic inertia through institutional intervention however may take decades. Demographic inertia exists at SSU as a consequence of previous hiring, retention and promotion practices. Through demographic inertia’s maintenance of the entrenched faculty population structure, it limits the rate of increase in the representation of women faculty. This study reveals four major points concerning the effectiveness of intervention strategies such as ADVANCE at overcoming demographic inertia. First, despite aggressive institutional intervention programs, demographic inertia will make changing the established faculty population structure challenging. Second, among the various models, men and women’s vital parameters differ in a number of meaningful ways; many of women’s demographic rates improved while some of men’s demographic rates declined following the implementation of ADVANCE. Third, the change in women’s vital parameters following ADVANCE increased both the rate of change in women’s representation and their population growth rate, however most of their growth occurred in the assistant professor population. Finally and perhaps most importantly, although institutional intervention is effective at
minimizing demographic inertia, improving women’s representation at a reasonable pace requires continued positive growth of the university faculty population.

Population Structure

Previous hiring and promotion practices employed by SSU are responsible for the differences currently observed in the structure of men and women’s S&E faculty populations. Traditionally, women were primarily hired at the rank of assistant professor while men were hired at all three faculty ranks. The diverse recruitment of men at all three faculty ranks coupled with high promotions rates of male assistant and associate professors enabled the male assistant, associate and full ranks to grow at similar rates and with fairly equal population sizes. Men are currently more evenly distributed among the three faculty ranks than women; this imbalance is projected to persist into the future. According to our models, the only future changes expected to occur to men’s population structure include a small increase in the number of male assistant professors and a small decrease in the number of male full professors.

In comparison, growth in the number of associate and full female professors relies almost entirely upon promotions. The “all years”, and pre-ADVANCE scenarios do support a modest recruitment of female associate professors but in the ADVANCE scenario, women are hired solely as assistant professors. The total population of women faculty is projected to grow over the next 30 years however the majority of this growth will occur through the recruitment of new assistant professors. High recruitment of female assistant professors will produce a rapid growth in the number of women in this
rank while female associate and full professor ranks experience much slower rates of growth. Continued strong growth in the number of female assistant professors with slow growth in the number of associate and full women will work to preserve the current population structure. Differences in men and women’s population structures permit demographic inertia to exert strong control retarding the pace of change in women’s representation.

**Vital rates and population growth rates comparisons**

The faculty population size of women scientists and engineers at Snow State University is 1/5 that of S&E men therefore small annual changes to the population of women faculty through recruitment or attrition during 1998-2007 had large effects on their vital parameter estimates. Standard errors and confidence intervals of vital parameter estimates for women are larger than standard errors and confidence intervals of vital parameter estimates for men. Even though we are less certain about the parameter estimates for women, we can still make meaningful gender vital rate comparisons. Although a greater number of men left SSU than women from 1998-2007, the proportion of the populations lost through attrition are almost equal for men and women. The ratio of new hires to total population is higher for women than men in all three scenarios: “all years”, pre-ADVANCE and ADVANCE. This combination of proportionally similar attrition for men and women coupled with higher proportional female recruitment is responsible for women faculty’s larger population growth rates in all three models.

Women’s population growth rates are consistently higher than men’s but vary between models and are smallest under the pre-ADVANCE scenario and largest under
the ADVANCE scenario. The women’s ADVANCE model’s high population growth rate is the result of improvements in the recruitment rate of assistant professors and in the promotion rate of associate professors coupled with a reduction in the attrition rate of assistant professors. Not all vital rates showed a sizeable or positive change between the pre-ADVANCE and ADVANCE models. For example, the use of tenure-clock extensions was more common during ADVANCE than the years prior to ADVANCE. Increased use of tenure-clock extensions during ADVANCE prevented large improvement in the promotion rate of female assistant professors. Also, female full professor attrition rates were higher during ADVANCE than prior to ADVANCE. During the ADVANCE years, due to retirement in all but one case, at least one woman full professor left SSU annually.

Changes in the male faculty’s vital rates during ADVANCE served to reduce men’s population growth rate relative to the population growth rate they experienced pre-ADVANCE. The male population at all three faculty ranks experienced reduced promotion rates and increased attrition rates during ADVANCE. Also, the recruitment rate of male assistant professors increased while those of male associate and full professors decreased. In the ADVANCE model, the number of male full professors is projected to decrease over 30 years due to a slight increase in their attrition, a reduction in their recruitment and a decrease in the promotion rate of associate to full professors. During ADVANCE, SSU instigated university wide changes in the requirements necessary for promotion and these changes are likely responsible for the reduction in male associate professor’s promotion rates following ADVANCE.
Exponential population growth occurs in all six matrix models with the most dramatic exponential growth occurring at the rank of female assistant professor. Exponential growth is present in population matrix models when the dominant eigenvalue is real, positive and larger than one as is the case in all six of the matrix population models formulated in this study.

Projected sex ratios

All three models project changes in the faculty sex ratios towards equitable gender representation over the next 30 years. The rate of sex ratio change, however, is based on the assumption of continued positive S&E faculty population growth. The number of part-time/adjunct academic faculty employed by our nation’s academic institutions is on the rise potentially at the expense of full time tenured/tenure-track faculty (Conley and Leslie, 2002; Ehrenberg, 2006). Should the population size of SSU’s full time tenured/tenure-track faculty stagnate, our models’ projections may prove overly optimistic.

Given continued positive population growth, our models show that movement towards equitable gender representation will occur most quickly in the ADVANCE model where women reach 30% of assistant, associate and total professors within 1, 11 and 12 years respectively. The ADVANCE model projects exact parity between men and women assistant, associate and total faculty in 13, 13 and 22 years respectively. Despite the ADVANCE model’s optimistic vital rates, demographic inertia manages to limit the representation of female full professors; they are not projected to reach either 30% or
50% representation within 30 years. One note of caution, ADVANCE's projected growth rate for female faculty depends on continued, sharp exponential faculty growth.

The pre-ADVANCE model projects a less rosy picture for women faculty's future representation than the ADVANCE model. In the pre-ADVANCE model, the representation of female assistant and associate professors is projected to reach 30% in 11 and 19 years respectively. Women full professors and the total number of women professors are not projected to reach 30% within 30 years. Exact parity with men is not projected under pre-ADVANCE conditions at any faculty rank within the next 30 years. If pre-ADVANCE demographic rates persist, despite continued growth of the faculty population, improvements in the representation of women full professors and the overall number of women professors will occur at a distressingly slow pace.

Future demographic rates are likely to vary somewhere between the pre-ADVANCE and ADVANCE extremes. Both the "all years" mean matrix and the stochastic simulation represent middle of the road scenarios. They project women's assistant, associate and total population representation to reach 30% within 30 years. The "all years" matrix projects parity between men and women assistant and associate professors within 30 years.

In the "mixed-model" projection, we looked at the impact that a short term boost in women's demographic rates followed by a reversion back to less optimistic, pre-ADVANCE vital rates has on women faculty's representation at SSU. This modeling scenario was motivated by recent events at the Massachusetts Institute of Technology (MIT) in their efforts to diversify their S&E faculty. MIT's 1996 report, "A Study on the Status of Women Faculty in Science at MIT" (Massachusetts Institute of Technology...
[MIT], 1999)" described the situation for women science faculty at MIT at the time and represents the first time a prestigious U.S. research institution recognized and responded to inequalities between men and women faculty. They acknowledged that from 1975 to 1996 the number of women science faculty at MIT had stagnated, and in an effort to counteract women’s blatant under-representation at MIT they enacted aggressive administrative reforms to promote the recruitment of women junior faculty. The institutional intervention executed by upper MIT school of science administration quickly proved effective at recruiting qualified women scientists for junior faculty positions. However, in 2000, after 5 years of improvements in women’s representation among science faculty, new MIT science administrators relaxed some of the more progressive policies aimed at promoting the representation of women and once again the number of female science faculty stagnated (Hopkins, 2006). The situation at MIT exposes the vulnerability of generating long term change in women’s representation while begging the question, “What long-term improvements in women’s representation are feasible given short-term institutional intervention?”. Our “mixed-model” scenario addresses this question at Snow State University and shows that despite initial gains in women’s representation at the ranks of assistant and associate professors during the five years of ADVANCE, the pace of improvement slows down following a reversion back to pre-ADVANCE rates. Over the long run, this scenario projects negligible change in the representation of full female faculty and sluggish improvements in the representation of assistant and associate faculty following the initial gains achieved with the intervention program. The phenomenon observed at MIT is probably not unique to that institution and our models show how a situation similar to MIT’s would play out at SSU. We found that
steady increases in women’s representation among university faculty will require continued improvement to women’s recruitment, retention and promotion rates.

Our study also reveals differences between men and women in time spent in their faculty ranks. Women labor longer as assistant and associate professors than men, a trend that has been identified at a number of prominent U.S. academic institutions including the University of California at Berkley, Duke University and MIT (NAS, 2006).

Surprisingly, women spent more time as assistant professors under ADVANCE than prior to ADVANCE. As mentioned earlier, assistant professors rarely used tenure-clock extensions prior to ADVANCE but have since increased their use. Increased use of tenure-clock extensions has not only impacted the promotion rate of assistant women faculty but has also increased their time spent in rank. Female associate professor’s time spent in rank was twice that of men’s pre-ADVANCE but was greatly reduced under ADVANCE. Most female full professors are new to their rank therefore their duration as full professors is considerably shorter than male full professors’ time spent in rank.

Perturbation analysis gives us insight into potentially effective intervention strategies for promoting women faculty’s representation at SSU and other academic institutions. As we’ve previously discussed, growth of the women associate and full faculty populations are challenged by current hiring practices. Perturbation analysis showed that women’s population growth rate would respond quickly to increased recruitment at the assistant and associate professor ranks. Previous studies (Hargens and Long, 2002; Marschke, et al. 2007) assumed that recruitment occurs solely at the assistant faculty rank and failed to identify the impact that diversified recruitment has on minimizing demographic inertia. Our models show that since ADVANCE was
implemented, female assistant professor’s non-retirement attrition rates have decreased while the sensitivity analysis indicates that lowering assistant professor attrition has a strong positive impact on population growth rate. If women continue to be hired largely at the rank of assistant professor, high retention of female assistant professors will eventually, albeit slowly, improve the overall representation of women among S&E university faculty at all three faculty ranks. The eventual improvements in women’s representation at the associate and full professor ranks primarily through increased recruitment and retention of assistant professors will do little, however, to alter women faculty’s population structure.

The perturbation analysis also indicates that women’s population growth rates are not sensitive to increases in the hiring rate of female full professors. Despite this, achieving a rapid improvement in the representation of female full professors will require hiring at this rank. There is limited availability of female full professors for recruitment as they are severely underrepresented and are in high demand therefore hiring female full professors will prove challenging. Because of the high demand for women with full professor rank nationally at other academic institutions and in industry, SSU should make the retention of female full professors a priority. Improvements in the representation of female full professors will also require continued growth in the promotion rate of female associate professors. Should SSU neglect to implement actions to improve the representation of female full professors by improving their recruitment and retention rates then it will be nearly impossible to alter the entrenched faculty population structure; focusing on the promotion and advancement of assistant and associate professors alone will prove insufficient.
This study corroborates results from previous studies by Hargens and Long (2002) and Marschke et al. (2007) that found demographic inertia to be a barrier preventing improvements in women faculty's representation. Marschke et al. (2007) showed that, in the absence of positive faculty population growth, it will take over 30 years for women's representation to reach 34% while Hargens and Long (2002) estimated 35 years for women to match their representation in the job applicant pool. Our projections are somewhat more optimistic than either Hargens and Long (2002) or Marschke et al. (2007) likely because we included continued faculty population growth, and recruitment of faculty at all three faculty ranks in our models. In the Marschke et al. (2007) study, they found that the pace to reach equality in the representation of women faculty can be accelerated by hiring, promoting and retaining men and women faculty at identical rates. Our study also found that overcoming demographic inertia will require improvements to women faculty’s vital rates. Our application of matrix population models allowed us to pin-point the influence of specific demographic rates on faculty population change and growth rather than relying on the manual manipulation of demographic rates as done in previous studies. Finally, our model is stage classified, not age classified which allowed us to investigate changes in the representation of women at specific faculty ranks. This is important since the under-representation of women full professors is especially pronounced. By stage classifying, we are not limited to making broad suggestions regarding intervention strategies effecting the overall population of female faculty. Instead, we have determined the demographic issues that are unique to specific faculty ranks while extrapolating how these specific faculty rank level issues impact women’s total representation relative to men. Such information can be used for
formulating both rank specific and overall population level intervention strategies aimed at improving women's representation among university faculty.

In conclusion, our study found that demographic inertia limits women's representation at SSU. We examined the effectiveness of ADVANCE at promoting and retaining women scientists and engineers at SSU and posit that intervention strategies such as ADVANCE help overcome demographic inertia. Although combating it takes time, institutional intervention will shorten the time required for overcoming demographic inertia. Previous studies and reports (e.g. Handelsman et al., 2005; Marschke, 2007, NAS, 2006) have made a number of suggestions of ways to improve women's recruitment, retention and promotion rates in a university setting. For the specific purpose of combating demographic inertia to improve women's representation among university faculty, we suggest considering the following recommendations:

1. Diversify faculty hiring practices by increasing recruitment of women associate and full faculty.
2. Decrease time women spend as associate professors by increasing promotion rates of women associate professors to full professors.
3. Increase retention rates of women once they are promoted to full professor rank.
4. Maintain high retention rates of assistant women faculty.
5. Encourage continued growth of full time tenured/tenure-track faculty population.
### Tables

Table 1. New hire and attrition counts for male and female S&E faculty from 1998-2007. The 2007 attrition data was not yet available at the time of model formulation.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New Hires</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assistant</td>
<td>8</td>
<td>12</td>
<td>10</td>
<td>10</td>
<td>15</td>
<td>8</td>
<td>13</td>
<td>13</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Associate</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Full</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>16</td>
<td>15</td>
<td>14</td>
<td>16</td>
<td>10</td>
<td>15</td>
<td>17</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assistant</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>9</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Associate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Full</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>9</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Attrition</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assistant</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>8</td>
<td>7</td>
<td>4</td>
<td>NA</td>
</tr>
<tr>
<td>Associate</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>7</td>
<td>NA</td>
</tr>
<tr>
<td>Full</td>
<td>14</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>11</td>
<td>NA</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>15</td>
<td>9</td>
<td>12</td>
<td>13</td>
<td>12</td>
<td>16</td>
<td>18</td>
<td>18</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assistant</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>NA</td>
</tr>
<tr>
<td>Associate</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>NA</td>
</tr>
<tr>
<td>Full</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>NA</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>NA</td>
</tr>
</tbody>
</table>
Table 2. Mean projection matrices $A_{it}$, $i =$ men, women and $t =$ all years, pre-ADVANCE and ADVANCE

<table>
<thead>
<tr>
<th></th>
<th>All years</th>
<th>pre-ADVANCE</th>
<th>ADVANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.181</td>
<td>0.029</td>
<td>0.022</td>
</tr>
<tr>
<td>0.779</td>
<td>0.817</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.122</td>
<td>0.102</td>
<td>0.882</td>
<td>0</td>
</tr>
<tr>
<td>0.098</td>
<td>0</td>
<td>0.077</td>
<td>0.955</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WOMEN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.241</td>
<td>0.002</td>
<td>0</td>
</tr>
<tr>
<td>0.981</td>
<td>0.853</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.019</td>
<td>0.075</td>
<td>0.931</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0.044</td>
<td>0.922</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>All years</th>
<th>pre-ADVANCE</th>
<th>ADVANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.181</td>
<td>0.029</td>
<td>0.022</td>
</tr>
<tr>
<td>0.779</td>
<td>0.817</td>
<td>0.814</td>
<td>0</td>
</tr>
<tr>
<td>0.122</td>
<td>0.102</td>
<td>0.890</td>
<td>0</td>
</tr>
<tr>
<td>0.098</td>
<td>0.110</td>
<td>0.80</td>
<td>0.956</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WOMEN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.241</td>
<td>0.002</td>
<td>0</td>
</tr>
<tr>
<td>0.981</td>
<td>0.853</td>
<td>0.832</td>
<td>0</td>
</tr>
<tr>
<td>0.019</td>
<td>0.075</td>
<td>0.965</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0.011</td>
<td>0.971</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>All years</th>
<th>pre-ADVANCE</th>
<th>ADVANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.181</td>
<td>0.029</td>
<td>0.022</td>
</tr>
<tr>
<td>0.779</td>
<td>0.817</td>
<td>0.814</td>
<td>0</td>
</tr>
<tr>
<td>0.122</td>
<td>0.102</td>
<td>0.890</td>
<td>0</td>
</tr>
<tr>
<td>0.098</td>
<td>0.110</td>
<td>0.80</td>
<td>0.956</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WOMEN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.241</td>
<td>0.002</td>
<td>0</td>
</tr>
<tr>
<td>0.981</td>
<td>0.853</td>
<td>0.832</td>
<td>0</td>
</tr>
<tr>
<td>0.019</td>
<td>0.075</td>
<td>0.965</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0.011</td>
<td>0.971</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>All years</th>
<th>pre-ADVANCE</th>
<th>ADVANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.181</td>
<td>0.029</td>
<td>0.022</td>
</tr>
<tr>
<td>0.779</td>
<td>0.817</td>
<td>0.814</td>
<td>0</td>
</tr>
<tr>
<td>0.122</td>
<td>0.102</td>
<td>0.890</td>
<td>0</td>
</tr>
<tr>
<td>0.098</td>
<td>0.110</td>
<td>0.80</td>
<td>0.956</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WOMEN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.241</td>
<td>0.002</td>
<td>0</td>
</tr>
<tr>
<td>0.981</td>
<td>0.853</td>
<td>0.832</td>
<td>0</td>
</tr>
<tr>
<td>0.019</td>
<td>0.075</td>
<td>0.965</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0.011</td>
<td>0.971</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>All years</th>
<th>pre-ADVANCE</th>
<th>ADVANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.181</td>
<td>0.029</td>
<td>0.022</td>
</tr>
<tr>
<td>0.779</td>
<td>0.817</td>
<td>0.814</td>
<td>0</td>
</tr>
<tr>
<td>0.122</td>
<td>0.102</td>
<td>0.890</td>
<td>0</td>
</tr>
<tr>
<td>0.098</td>
<td>0.110</td>
<td>0.80</td>
<td>0.956</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WOMEN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.241</td>
<td>0.002</td>
<td>0</td>
</tr>
<tr>
<td>0.981</td>
<td>0.853</td>
<td>0.832</td>
<td>0</td>
</tr>
<tr>
<td>0.019</td>
<td>0.075</td>
<td>0.965</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0.011</td>
<td>0.971</td>
</tr>
</tbody>
</table>
Figure 2. The effect of mean projection matrix and stochastic simulation on population growth rates, \( \lambda_j \). Gray bars = male matrices and white bars = female matrices.
Figure 3. Number of assistant, associate and full male and female science and engineering professors at Utah State University from 1998-2007.

Figure 4. Stable stage distribution of men and women faculty as projected by the 1998-2006 mean projection matrix. Gray = assistant professors, white = associate professors and black = full professors.
Figure 5a. 1998-2006 mean projection matrix projected ratios of women/men faculty over 30 years: Light, gray circles = new hires, solid black line= assistant professors, solid dark gray line = associate professors, black line with circle markers = full professors and dashed medium gray line = total professors.

Figure 5b. Pre-ADVANCE mean projection matrix projected ratios of women/men faculty over 30 years: Light, gray circles = new hires, solid black line= assistant professors, solid dark gray line = associate professors, black line with circle markers = full professors and dashed medium gray line = total professors.
Figure 5c. ADVANCE mean projection matrix projected ratios of women/men faculty over 30 years: Light, gray circles = new hires, solid black line = assistant professors, solid dark gray line = associate professors, black line with circle markers = full professors and dashed medium gray line = total professors.

Figure 5d. Mixed-model where ADVANCE model is projected for 5 years followed by projection of pre-ADVANCE model for 25 years, projected ratios of women/men faculty over the total 30 years: Light, gray circles = new hires, solid black line = assistant
professors, solid dark gray line = associate professors, black line with circle markers = full professors and dashed medium gray line = total professors.

Figure 6. Stochastic simulation projected women/men ratio of mean population sizes of assistant, associate and full professors estimated from 10,000 realizations projected each for 30 time steps.
Figure 7. Sensitivities of the population growth, $\lambda$, to changes in the entries of the 1998-2006 mean projection matrix.
Figure 8a. Mean stage durations for male and female assistant professors as estimated by the “all years”, pre-ADVANCE and ADVANCE projection matrices.

Figure 8b. Mean stage durations for male and female associate professors as estimated by the “all years”, pre-ADVANCE and ADVANCE projection matrices.
Figure 8c. Mean stage durations for male and female full professors as estimated by the “all years”, pre-ADVANCE and ADVANCE projection matrices.
References


