Measuring the Effect of Role Models on Women in Science at Swarthmore College

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Abstract: We examine the effect of female faculty and older female majors on the number of women majoring in the sciences. According to psychological and educational theory, the presence of female faculty and older students may encourage women to pursue their interests in the sciences. We test this using data from the Swarthmore College natural science departments from 1981-2001. After allowing for fixed effects in each department, we find that the number of role models has no effect on the number of female majors. While this does not preclude the possibility that role models have an effect on the number of female majors, it demonstrates that the effect is not based on the number of available older women.

Introduction

Women make up almost half the workforce, but occupy only 22% of science, engineering, and technology jobs (Hanson, Schaub, Baker 1996). This differential deprives society of scientific talent that could be put to better use. Much of the gender difference in the workforce stems from the choices that students make in college; if a woman decides not to major in a scientific field, it will be harder for her to move into a technological area. In fact, much of the gender difference in earnings comes from the choice of major (Jacobs 1996). Thus, we focus on college as a time to study what affects the number of women in the sciences. Because half of all college students change majors (Jacobs 1996), college is an important time to try to retain or even gain women with interest in the sciences, so that they may go on to have scientific careers.

The Status of Women in Science

Women have made progress in some of the sciences in the last thirty years, but this progress has not been uniform and has slowed down over time. In 1960, 13.7% of degrees awarded to women were in sciences and engineering. This number increased to 22.7% in 1976 and has stayed constant since then. At the same times, 44.4% and then 38.9% of degrees awarded to men were in science and technology (Barber 1995). However, much of this desegregation of majors has occurred in medicine, biology, law and business, while engineering and the physical sciences have stayed male-dominated (Davies and Guppy 1997). The gender divide between life sciences, such as biology and medicine, and physical sciences widened between 1976 and 1989, even after academic preparation was controlled for (Turner and Bowen 1999).

The level of science participation of women decreases as one moves to higher educational levels. At least 40% of biology, chemistry, and math students in twelfth grade are female, though only 22% of twelfth-grade physics students are female (Hanson, Schaub, Baker 1996). In college, women make up more than half of enrolled students and bachelor's degree recipients, but only 27.6% of all science majors are female (Hanson, Schaub, Baker 1996). Even when high school preparation and the amount of career- or family-focus of an individual is controlled for, gender is the best predictor of whether a person will go into engineering (Yauch 1999). As students move on to graduate school, the gender divide grows wider.

In addition, women are more underrepresented in sciences at higher-ranking colleges and universities. Women are particularly unlikely to go into highly selective programs like engineering at highly selective schools (Davies and Guppy 1997). Also, there are fewer women as students or faculty in the sciences at high-ranking and doctorate-granting institutions (Radke Sharpe and Sonnert 1999). Thus, the divide between the genders is even more dramatic at those schools which are considered the best preparation for going into the sciences.

Motivations of Women to Major in the Sciences

The reasons that students choose to major in sciences vary across genders and individuals. Three major areas that affect this choice are the student's belief that she can succeed, her perception of the future of her major in the labor market, and her innate abilities.

The first two of these may be affected by a student's college experience, so we focus more on these.

Self-efficacy beliefs, a person's beliefs about whether he or she can succeed in a particular area, have a strong effect on whether a person chooses to attempt something. These beliefs are shaped by four factors: a person's own past successes and failures, the successes and failures of those whom the person sees as similarly capable, what others tell the individual, and the individual's emotional and mental state (Zeldin and Pajares 2000). Psychologists have found that women are more affected by the successes of others and by what others say than men are. This means, for example, that negative stereotypes of the sciences – particularly of computer science and engineering – are more likely to dissuade women than men (Camp 1998). This may also mean that women are more affected by the presence of individuals who are like them, including older female students and female faculty. In addition, the encouragement and discouragement that women receive from their families, faculty, and others may have a strong effect on whether they continue in the sciences. Perhaps because of these effects, women tend to have lower self-efficacy perceptions in the sciences. This is true even when they are as capable as males (Zeldin and Pajares 2000). In addition, women tend to put more pressure on themselves to excel, believing that they must be more successful than males in order to major in the sciences (Ware, Steckler, and Leserman 1985); this means that women who have been as successful as men are more likely to leave the sciences, believing that they are not smart enough.

A woman's potential to succeed in the labor market is also an important factor in whether a woman would choose a science major that would lead to it. Some labor market segregation exists in the sciences, which means that the return to a science education is lower for a woman than for a man (Davies and Guppy 1997). In addition, the culture of the sciences is often seen as masculine or even hostile to women and the way they were socialized (Barber 1995). Female students often anticipate resentment from male colleagues in the sciences (Morgan 1992); this often happens as young female faculty in the sciences feel isolated in their departments (Nolan 1992) and women in the sciences feel less respected than their male colleagues (Hughes 2000). Thus, the potential negative aspects of the labor market may outweigh the returns that women would receive, so that they choose to enter other fields instead.

The issue of combining a family with work also affects women's labor market decision, particularly in the sciences. Women are likely to work fewer years, so that the returns to any education are lower (Jacobs 1996). This may explain why, even after academic preparation is controlled for, men are more likely to enter higher-paying fields than women are (Davies and Guppy 1997). The challenges of combining work and family are even more acute in laboratory-based sciences, which cannot have flexible hours (Morgan 1992). The issues that affect all professional majors affect the sciences as well, further influencing the number of women in the sciences.

Older scientific women in colleges may affect the number of female science majors by affecting some of the factors previously mentioned. Most important is the role of mentoring. Older female scientists are able to show that science is normal for women, to model someone of the same gender who is successful and to challenge the overly high expectations that many female students have (Wares, Steckler and Leserman 1985, Zajares and Pajares 2000). Older women may also be able to integrate younger women into a department that is dominated by the social assumptions of males, making women feel socially comfortable in a science department (Nolan 1992).

In addition, the teaching styles of female faculty may affect female students' success, which may encourage them to be majors. Female instructors are perceived as respecting both genders equally and knowing their students better (Hughes 2000). Perhaps because of this, female students are more likely to speak up in a large class with a female professor than with a male professor, according to Canada and Pringle (1995), suggesting that female professors may make female students feel more comfortable in class. Finally, according to the testing style of female faculty may be more attuned to the skills of female students (Robb and Robb 1999).

The existence of female faculty in the natural sciences does not guarantee that role modeling will occur. Many researchers (Robst, Keil and Russon 1998, Canes and Rosen 1995, Nixon and Robinson 1999) have noted that role models need not be similar in gender; they may be like students in terms of race, religion, or other characteristics. In addition, Robb and Robb (1999) have conjectured that the women who have persisted in the sciences have become more "masculine" in order to survive, and thus cannot relate as well to female students. Thus, it may not be safe to assume that all older women are role models or that all role models are women.

Previous Results

Various researchers have considered the relationship between having female professors and educational outcomes. Nixon and Robinson (1999) found that having more female faculty and staff in high schools increases female educational attainment statistically significantly, though not economically significantly. Tidball (1986) found that having more female faculty in an undergraduate institution is associated with more women going on to receive doctorates in science. Radke Sharpe and Sonnert (1999) found a positive relationship between the number of female math faculty in one year to the proportion of female majors in the next year. Finally, Robst (1998) found a strong positive link between the number of female faculty and the number of women in the sciences that returned for a second year of study at SUNY-Binghamton. These studies suggest some relationship between the number of female faculty and the number of female students in the sciences, but it is hard to know how strong it is, particularly once school characteristics are controlled for.

One important study that casts doubt on this link is from Canes and Rosen (1995). Looking at three colleges of different types, they found that once the fixed effect of a department is controlled for, the percentage of majors that are female in that department is not related to the percentage of professors who are female. Canes and Rosen found that this result was also true when only the sciences were considered. We extend this study by considering some other functional forms, more recent data, and data from a different college.

Data

The data I use are provided by the offices of Institutional Research and the Provost at Swarthmore College. Swarthmore College is a small, private, coeducational liberal arts college that offers only bachelor's degrees. This focus on undergraduates may increase the number of women in the sciences, particularly because Swarthmore has a low student-faculty ratio (Radke Sharpe and Sonnert 1999, Tidball 1986). It is considered one of the most selective liberal arts colleges, and is one of few liberal arts colleges to offer an engineering major. The selectivity of Swarthmore may counteract the effect of being a small college, since selective schools are less likely to have women in selective programs like engineering or the sciences (Davies and Guppy 1997). The effect of being a small liberal arts college seems to be stronger, at least in doctorate production for women. According to Tidball (1986), Swarthmore was one of the most productive schools in terms of natural science doctorates for both men and women from 1970-1979; it is still ranked in the top ten of liberal arts colleges for doctorates awarded to graduates.

Measures of the numbers of students and professors are for each department in the Natural Sciences Division at Swarthmore College, which consists of biology, chemistry, computer science, engineering, mathematics and statistics, and physics and astronomy. Special majors, such as interdepartmental majors (biochemistry being the largest) and majors that fall outside traditional departments but are still considered science have been removed since they are not closely associated with the faculty of one department. Computer science was considered a special major until 1999, but it is included as a department in each year that there were both professors classified as being in the department and majors in the department (each year after 1990). Though astronomy, physics, and astrophysics are listed as separate majors, they are combined since physics and astronomy is considered one department.

The dependent variables I will be studying are the number and fraction of graduating majors that are female in each natural science department in each year. If a person majors in more than one natural science department, he or she is included once in each department; this means that the total number of natural science majors is less than the sum of the majors over all the departments. The fractions and numbers in each major and overall are summarized in Table 1. As can be seen from Chart 1, the percentage of female majors in these departments has varied around 40%, and does not seem to have any trend over time.

The independent variables of interest are the lagged number or fraction of female majors for the previous three years and the number or fraction of professors in the department who are female. The professor data are based on the number of tenured and tenure-track faculty. According to the Provost's office, most non-tenure-track faculty in the sciences are leave replacements and adjuncts who are at Swarthmore for only one year. Thus, it is less likely that their presence would provide a longer term mentoring effect. The values for the professor data for each department are summarized in Table 2. Unlike the percentage of female science majors, the percentage of female science faculty shows a clear upward trend; see Chart 2. In order to control for the number of potential female science majors, we also include the number or percentage of women graduating from Swarthmore in each year. This variable is the same for all departments in a given year, and is summarized in Table 3.

Model & Estimation Methods

To describe the possible role models for a woman in the sciences most accurately, we include all the role models she might encounter during a college career of four years. Thus, we include the female faculty from all four years that a woman would normally be in college and the female majors from the three previous years. Thus, the number of women in the sciences in the graduating class at time T depends on the majors from years T–1, T–2, and T–3 and the faculty from years T, T–1, T–2, and T–3.

To control for the fact that some departments may be more likely, all else equal, to attract female majors, we add a different fixed effect, ϕ_i, for each department. We consider models with both the absolute numbers of role models and the percentages of older students and faculty that are female. We also consider models where the effect occurs in the total number of female majors and in the percentage of majors that are female. The descriptions and variable names are listed in Table 4. The models estimated are:

(1) $pmajor_{it} = \alpha + (\beta_1, \beta_2, \beta_3)*(fmajor_{i,t-1}, fmajor_{i,t-2}, fmajor_{i,t-3}) + (\gamma_0, \gamma_1, \gamma_2, \gamma_3)*(fprof_{i,t}, fprof_{i,t-1}, fprof_{i,t-2}, fprof_{i,t-3}) + \delta*pgrads_t + \phi_i + \varepsilon_{it}$
(2) $pmajor_{it} = \alpha + (\beta_1, \beta_2, \beta_3)*(pmajor_{i,t-1}, pmajor_{i,t-2}, pmajor_{i,t-3}) + (\gamma_0, \gamma_1, \gamma_2, \gamma_3)*(pprof_{i,t}, pprof_{i,t-1}, pprof_{i,t-2}, pprof_{i,t-3}) + \delta*pgrads_t + \phi_i + \varepsilon_{it}$
(3) $fmajor_{it} = \alpha + (\beta_1, \beta_2, \beta_3)*(fmajor_{i,t-1}, fmajor_{i,t-2}, fmajor_{i,t-3}) + (\gamma_0, \gamma_1, \gamma_2, \gamma_3)*(fprof_{i,t}, fprof_{i,t-1}, fprof_{i,t-2}, fprof_{i,t-3}) + \delta*fgrads_t + \phi_i + \varepsilon_{it}$
(4) $fmajor_{it} = \alpha + (\beta_1, \beta_2, \beta_3)*(pmajor_{i,t-1}, pmajor_{i,t-2}, pmajor_{i,t-3}) + (\gamma_0, \gamma_1, \gamma_2, \gamma_3)*(pprof_{i,t}, pprof_{i,t-1}, pprof_{i,t-2}, pprof_{i,t-3}) + \delta*fgrads_t + \phi_i + \varepsilon_{it}$

We estimate these models using fixed effects by including a dummy variable for each department, with biology omitted.

Results

As can be seen from the full results in Table 5, almost no role model effect is found. Female faculty have no effect in any model, as measured by an F-test of the joint significance of all the coefficients the coefficients for all four years. Older female majors have no effect in any model but the third. In this model, adding four female majors in either of the two previous years would increase the expected number of majors by one. However, the p-values on each of these coefficients (0.009 and 0.025) are high enough that we might be suspicious. Together, the two years might be jointly significant, but we are testing too many hypotheses over all the models to feel certain in rejecting the null hypothesis that older majors in any given year have any effect on the number of majors in that year.[1] Thus, we find no role model effect.

However, there is a very strong fixed effect for each department. We notice that biology, the omitted group, is significantly different from every other department, while there is also considerable and significant variety among the other departments. Thus, we find that the influence on the number of majors is from what the department is and not from the role models in it. This influence is strong even when we control for the effects of role models.

To describe the department effects, we consider the order of the departments from most majors to fewest majors, by looking at the coefficients on the fixed effects. When the percentage of majors is the dependent variable, we find that biology has the most majors, followed by chemistry, mathematics, engineering, physics, and finally computer science. This is the same order as we find when we consider the average percentage of majors, without controlling for anything else. When we consider total numbers of majors instead, we find again that biology continues to have the most majors, physics and computer science continue to have the fewest majors. Because engineering is a large department, however, it has the second largest number of female majors. The arrangement of chemistry and math depends on the model; the model in which the order of chemistry and math differs from the uncontrolled order is also the model where the previous major effects are significant. However, even this model hardly changes the order of the departments. Overall, departments vary greatly in how many female majors they attract; this effect is generally unchanged when we control for a possible role model effect.

These effects continue to hold if we drop biology and computer science, the departments with the most extreme numbers of female majors. They also hold if we regress on a dummy

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[1] Over four models, each with seven coefficients of interest, we might conduct 28 t-tests. If we use Bonferroni's method of multiple hypothesis testing (Rice 1995) to correct for this, we should reject only when the p-value exceeds $\alpha = 0.05/28 = 0.002$. Neither statistic is rejected at this level.

variable indicating whether there are any female faculty or older majors in a year instead of on the numbers. These effects are robust to adding a time trend. In addition, the departmental ordering and the lack of role model significance continue if we use Poisson regression or negative binomial models. Thus, these results seem to be robust to changes in the model.

Conclusion

We have shown that the number or percentage of potential female role models has no effect on the number or percentage of female majors in subsequent years. This does not preclude a more complex form of a role model effect. Perhaps male faculty and older students are role models as often as female faculty and older students. Perhaps not all older women are equally good role models, or perhaps women in other science departments can act as role models. Perhaps the role model effect is slow to act, so that female role models in college influence a woman's choice to go on to graduate school but not her choice of major. All of these are possible influences that are not accurately captured in the number of female older students and female faculty in the student's department. Thus, we have shown only that the role model effect does not exist in a simple form. Motivating women to continue in science at college will be more complex than just hiring more female faculty.

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Tables and Charts

Table 1: Summary of female majors by department

Department	Years Included	Mean (Total)	Standard Deviation	Mean (Proportion)	Standard Deviation
Biology	1981-2001	22.4286	6.6451	.6022	.0972
Chemistry	1981-2001	3.1908	1.3645	.4503	.2092
Computer Science	1990-2001	0.4167	0.6686	.0772	.1216
Engineering	1981-2001	5.4286	2.1686	.2350	.0994
Mathematics/Statistics	1981-2001	3.4286	2.2488	.2867	.1719
Physics	1981-2001	2.0952	1.0911	.2039	.1086
Overall	117 observations	6.6068	8.2095	.3270	.2165

Chart 1: Percentage of Science Majors who are female

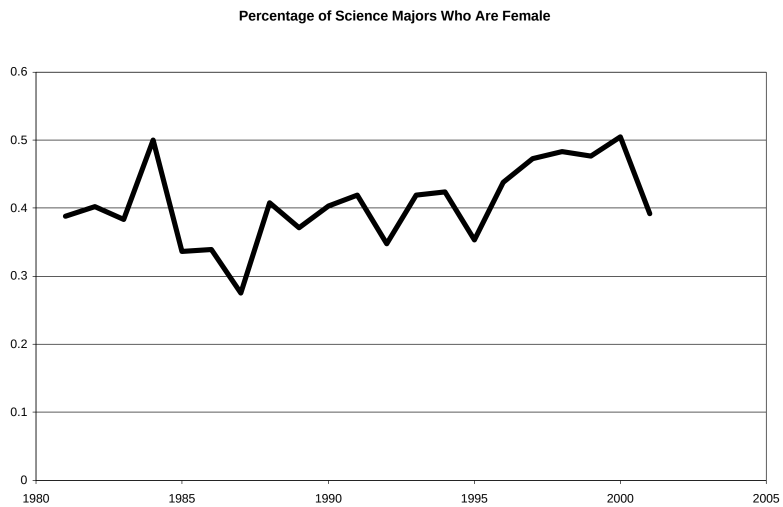

Table 2: Summary of female professors by department

Department	Years Included	Mean (Total)	Standard Deviation	Mean (Proportion)	Standard Deviation
Biology	1979-2001	3.130	1.290	.3206	.1109
Chemistry	1979-2001	1.696	.559	.2730	.0789
Computer Science	1990-2001	.750	.754	.3194	.2883
Engineering	1979-2001	.652	.463	.0740	.0524
Mathematics/Statistics	1979-2001	1.727	.890	.2086	.0776
Physics	1979-2001	1.174	.972	.1350	.1124
Overall	117 observations	1.637	1.213	.2198	.1514

Chart 2: Percentage of Science Faculty who are female

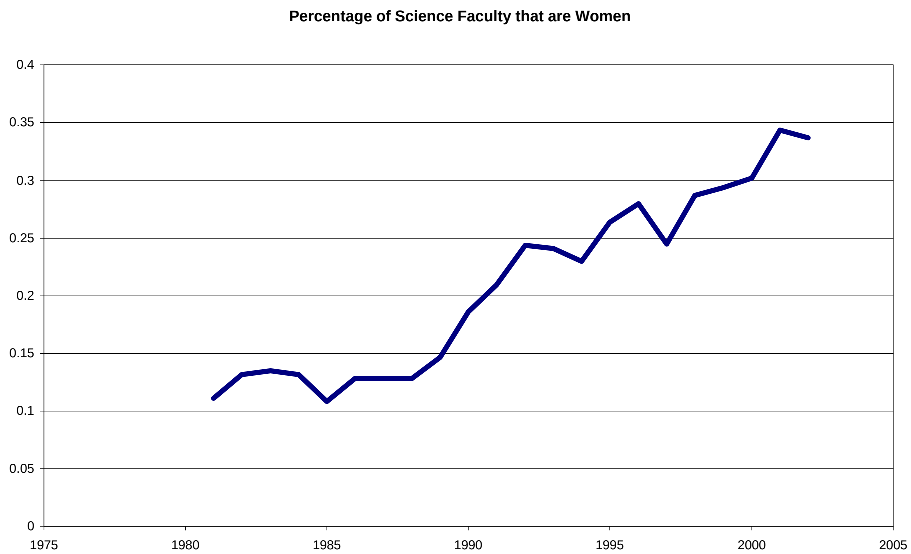

Table 3: Summary of control variable

Variable	Mean	Standard Deviation
Percentage Female Graduates	.4925	.0380
Total Female Graduates	164.86	23.17

Table 4: Variable names

Variable Name	Description
$pmajor_{it}$	Proportion of majors that were female in the year *t* and department *i*
$fmajor_{it}$	Number of female majors in the year *t* and department *i*
$pprof_{it}$	Proportion of professors that were female in the year *t* and department *i*
$fprof_{it}$	Number of female professors in the year *t* and department *i*
$pgrads_{t}$	Proportion of Swarthmore graduates that were female in year *t*
$fgrads_{t}$	Number of female Swarthmore graduates in year *t*

Table 5: Summary of regression results

Variable	Model 1 (Percent/Total)	Model 2 (Percent/Percent)	Model 3 (Total/Total)	Model 4 (Total/Percent)
Professor (Year of Graduation)	-0.0475 (.0376)	-0.2687 (.2460)	0.2998 (.7773)	2.1677 (5.9651)
Professor (Year before graduation)	0.0306 (.0517)	0.1240 (.3045)	0.3328 (1.0893)	1.3543 (7.4349)
Professor (Two years before graduation)	.0253) (.0528)	0.0175 (.3168)	0.4159 (1.1266)	1.5636 (7.8995)
Professor (Three years before graduation)	-0.0126 (.0414)	0.1670 (.2471)	-0.5029 (0.8449)	1.7534 (6.0130)
Majors (One year before graduation)	-0.0040 (.0050)	-0.1274 (.1211)	0.2841* (0.1066)	-0.2923 (2.8968)
Majors (Two years before graduation)	0.0024 (0.0052)	-0.0461 (.1193)	0.2476* (0.1090)	0.4963 (2.9084)
Majors (Three years before graduation)	0.0039 (0.0051)	0.0284 (.1133)	-0.0382 (0.1075)	-0.5446 (2.7828)
Women in graduating class	0.6956 (0.5365)	0.6772 (.5216)	0.0191 (0.0161)	0.0264 (0.0187)
Department Effects:				
Chemistry	-0.1065 * (0.1188)	-0.1540 * (0.0543)	-8.6738 * (2.4620)	-18.5337 * (1.3192)
Computer Science	-0.4992 * (0.1406)	-0.5828 * (0.1343)	-9.5899 * (2.8184)	-22.2193 * (3.2246)
Engineering	-0.3467 * (0.1125)	-0.4180 * (0.1048)	-6.9084 * (2.2750)	-15.2403 * (2.4864)
Math/Statistics	-0.2908 * (0.1160)	-0.3665 * (0.0824)	-8.7327 * (2.4081)	-18.0640 * (1.9823)
Physics/Astronomy	-0.3567 * (0.1257)	-0.4411 * (0.1068)	-8.9750 * (2.5821)	-18.9785 * (2.5481)
Constant	-0.0224 (0.2482)	0.0455 (.2406)	-0.9711 (2.5626)	0.8237 (3.1936)
F-Test: No Department Effects	F = 9.18 p = 0.0000 *	F = 4.32 p = 0.0015 *	F = 2.80 p = .0215 *	F = 45.04 p = 0.0000 *
F-Test: No Professor Effect	F = 0.46 p = 0.7630	F = 0.49 p = 0.7408	F = 0.53 p = 0.7124	F = 0.69 p = 0.6030
F-Test: No Older Major Effect	F = 0.43 p = 0.7332	F = 0.42 p = 0.7358	F = 6.24 p = 0.0007 *	F = 0.03 p = 0.9919
F-Test: No Role Model Effect	F = 0.44 p = 0.8735	F = 0.42 p = 0.8865	F = 4.22 p = 0.0005 *	F = 0.41 p = 0.8924

Standard errors in parentheses when applicable.
An asterisk (*) next to a result denotes that it is significant at the 5% level.