The impact of postdoc training on academic research productivity: what are the gender differences?

Yu Meng, *Georgia institute of Technology,* and Xuhong Su, *University of Georgia*

***Abstract*— This study examines how postdoc training affects scientists' research productivity in their early career years (the first three years after receiving their doctoral degrees), in an attempt to reveal whether postdoc training contributes to enforce women's lower productivity that has been well documented in the general S&E community . Using a nationally representative sample of academic scientists and engineering from research extensive universities (n=150), the study demonstrates that postdoc training boosts individual productivity in scientists' first three years; and the number of publications male scientists produce in the same period continues to outnumber that of female members. However, postdoc training, among these academic scientists and engineers, does not worsen women's disadvantageous status in productivity, and plays a neutral role in shaping individual productivity across the gender line .**

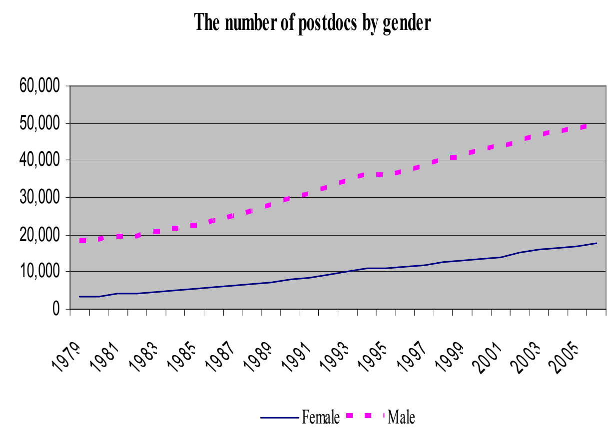

Fig. 1. The number of postdocs by gender over time (1979-2006). Source: The data were drawn from WebCaspar, National Science Foundation.

I. Introduction

MUCH light has been cast upon the rapid expansion of the postdoc enterprise during the past four decades. As can be seen from Fig. 1, the number of doctoral degree holders heading for postdoc training continues to increase. As of 2006, there were approximately 48 601 postdocs in doctorate-granting institutions, among which 34535 were working in S&E fields [1]. Within the most recent graduation cohort (2002-2005), the proportion of U.S.S &E doctorates participating into postdoc training reached 46%, with even higher percentages in life sciences and physical sciences [1].

The proliferation of the postdoc enterprise raised a great deal of concerns, which prompted researchers and policy makers to scrutinize its possible consequences. Does postdoc training indeed enhance scientific excellence in the U.S., or serve as a trap within which research talents gradually lose their momentum to advance their scientific careers [2,3,4,5]? Among many topics, one particular interest is to investigate how postdoc training shapes the internal stratification of the academic world.

The academic world has been stratified based on diverse factors, including but not limited to the categories of institutions [6], the ranking of academic departments [7,8], race [9] and gender [10, 11, 12, 13, 14]. It is the gender differences that we are particularly interested in. Past studies demonstrated that women faculty tend to face overwhelming barriers in their pursuit of academic careers, and especially so in science and engineering fields [11, 15]. As a result, women scientists have been consistently under-represented in the academic world, and drain more often than their comparable peers [16]. While multiple reasons may contribute to their disadvantages, one salient factor deserves special treatment: research productivity. In academic world, particularly in research universities, productivity proves a persistently positive relationship with where scientists are in the academic hierarchy. The puzzle [17] that women scientists publish less than their peers has almost turned into a theorem, though efforts to account for it are still pretty much needed.

The central research question is whether postdoc training serves as another mechanism to stratify academic community by gender or a level playing field for all academic scientists regarding scientific productivity. The question, though dedicated to advancing the understanding of academic world, bears enormous relevance to real policy programs. Recognizing the under-representation of female scientists in academic community, a good many programs were initiated to promote their status, among which postdoc fellowships were on the top list. Do more postdoc fellowships help women scientists to regain productivity equity in academic world? The question remains to be answered, and this study, focusing only on its impact on

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academic productivity, is a fist step to address the complicated consequences of these programs.

II. GENDER DIFFERENCES IN PRODUCTIVITY

Many studies concerned with women in science have found a gender gap in productivity to women's disadvantage [18, 19, 10]. On average, women publish fewer peer-reviewed journal articles than their male counterparts. The gap persists over time and across disciplines. Given that productivity is a significant factor in determining recognition, earnings and promotions, women scientists have suffered greatly due to their lower levels of productivity.

The efforts to reveal women scientists' career disadvantages (including but not limited to lower productivity levels) have been primarily invested on individual and institutional level factors. Decades of scholarly attention have attributed the incomplete integration of women in academic careers to their individual level determinants [10, 20], While individual level factors may explain part of women's disadvantage [21], recently, more and more scholarship has switched to examine how institutional factors shape the gender power stratification system [11, 12, 13, 22, 25]. A case in point is that in research universities, campus culture may continue to impose disadvantages upon women scientists [25]; gender devaluation, a process whereby women scientists receive less recognition and reward from the same amount of contribution to the body of scientific knowledge as their male peers, still finds its niche in women's way toward success [25].

How institutions shape scientists' productivity differently across the gender line has not been well resolved, though scholars start to claim the triumph that "most of the observed sex differences in research productivity can be attributed to sex differences in personal characteristics, structural position and marital status" [15]. While the old "productive puzzle" was successfully explained by a variety of identified institutional and individual factors, a new "puzzle" is raised in association with disparities in career trajectories by gender.

Extant literature provides rich evidence that postdoc training may boost scientists' academic productivity [2,8], and increase citation rates to their later publications [26].Nevertheless, this literature to a large extent addressed the effect of postdoc training on productivity for male scientists, leaving female scientists ignored due to their meager presence. One study particularly relevant to our focus investigated how postdoc fellowship interacted with gender to shape scientists' productivity, suggesting that postdoc fellowship experiences serve as a level playing field and enhance scientific productivity for both sexes. However, the study confined its population to those who obtained their doctoral degrees during 1955-1961, a couple of years even before the Title IX when women started to be effectively included into universities, raising the concerns whether the pattern reflected the unequal selection dynamics across gender, and questioning its possibility of persistence up to the time being. Another study bearing some relevant to ours was conducted by Sonnert [21], suggesting that the gender gap regarding productivity still exists among postdoctoral fellows. However, without any comparison to non-postdoc groups, the study does not allow for a reasonable detection of the effect of postdoc training on productivity.

The renewed interest on the relationship between postdoc training and sex differences in productivity derives its momentum from the drastic changes occurring in universities during the past few decades. Enormous strides have been made to include women into universities [25], though the field is well aware that the business has not been fully completed [15, 20, 23, 24]. Women doctorates heading for postdoc appointments follow the similar trend as male peers [Fig. 1], and have gained much ground in obtaining academic positions and receiving pivotal resources necessary for career success. Their status could not be so much improved without the intensive intervention from all kinds of funding agencies, such as NSF and NIH. Multiple programs have been initiated in an attempt to terminate gender inequity in academic community. Does postdoc training work neutrally or not across gender lines in shaping their productivity remains on the top question list to be answered.

III. DATA AND METHOD

Before turning to evaluate the impact of postdoc training on academic scientists' research productivity, the study starts with a detailed description of the dataset upon which the subsequent research can be performed. Ideally, to assess how postdoc training shapes academic scientists' research productivity, a study should take into account two intertwined processes: selection process and academic production process. The former process usually entails a longitudinal analysis examining sex differences in individual preferences toward postdoc training and the roles previous productivity plays. Past studies presented mixed findings. While female are less likely to take postdoc positions [28], some assurance is found that previous productivity, measured by both pre-doctoral publication and citation counts, showed no impact on individuals' exposure to postdoc experiences [26], and that the positive impact postdoc training has on academic employment appears not to vary across gender line [26].This study therefore focuses only on academic production process.

The data for this study are from "Research Value Mapping Survey of Academic Researchers", a study headquartered at Georgia Tech and based on a variety of data sources, including mailed questionnaire responses, curriculum vitae (CV) of the respondents and secondary data about universities and research centers. The present research combines both questionnaire responses and individual scientists' CVs.

The sampling frame was developed to represent the population of academic researchers working in "Research I" universities. Using the Carnegie List [6], the project retained universities (n=150) that produced at least one PhD in 2000 in at least one of 13 science and engineering fields [a] as defined by National Science Foundation (NSF) (NSF, 2000). The project collected the names of tenure-track faculty in each university by discipline from online university catalog or departmental websites. From the name list of each discipline, 200 male and female[b] academic scientists were then drawn.

The questionnaire was administered by mail, focusing in particular on the following domains of faculty activity: institutional affiliations, career timing and transitions, and working activities and attitudes. Along with the survey questionnaire, individual scientists' CVs were collected. The survey respondents were requested to provide their professional CVs or indicate their availability. In addition, researchers searched scientists' websites, university departments' websites and other public venues to maximize the incidence of CVs. All of the 1106 collected CVs were then coded into a database, with a particular emphasis on the following variables: educational background, the timing and the transitions of career development, and the number of peer-reviewed articles per year over their life cycles. Tests show that scientists with CVs were not significantly different than those without CVs available.

The information truncation in individual scientists' CVs is prevalent. It is not uncommon that some scientists skip the whole section of their employment history and/or research publications. As such, the sample for this study shrinks to 388.We assume the distribution on the key variables would not change by gender in the small sample, because no clues have been found in the existing literature that information truncation may vary significantly across gender. Combining both survey and CV data reflects a snapshot of academic scientists, and provides sufficient information to address the topic how postdoc training shapes academic scientists' research productivity and whether the impact varies across gender.

Previous studies demonstrate that research productivity is subject to the heavy influences of organizational contexts [22, 29, 26]. For instance, the effect of departmental prestige on individual productivity can be detected once scientists stay in the position for roughly three years [7]. To separate the effect of postdoc training from that of subsequent employment contexts, this study only examines academic scientists' productivity in the first three years after earning their Ph.D.s, and treats the individual productivity as a function of postdoc training, characteristics in doctoral training, and ascriptive attributes.

The dependent variable is the number of peer-reviewed articles published three years after the receipt of doctoral degrees. Given that academic employment is a highly selective process, especially so in research extensive universities, factors regarding doctoral training proved to exert significant influences. Previous studies show that the prestige of doctoral training affects their chances of being hired, and hence, needs to be controlled. The information was solicited by referring to three national evaluation reports on research-doctorate programs: *A Rating of Graduate Programs [30], An Assessment of Research Doctorate Programs in the United*

[a] Excluding health sciences and economics, the resulting disciplines include: biology, computer science, mathematics, physics, earth and atmospheric science, chemistry, agriculture, sociology, chemical engineering, civil engineering, electrical engineering, mechanical engineering, and materials engineering.

[b] Given the under representation of female faculty members in some disciplines, a census was conducted for those disciplines with less than 200 female members. Here are the fields: chemical engineering, civil engineering, material engineering, and mechanical engineering.

States [31, 32, 33], and *Research Doctorate Programs in the United States: Continuity and Change[34].* Each report covers six years before and after it was released. The prestige measures were generated by surveying carefully-selected faculty regarding the program's "effectiveness in educating research scholars/scientists." Based on the quarter ranking system, the departments were then classified as "highly effective", "strong", "marginal" and "unrated"[c].

Three other selection variables are also constructed to clarify the potential spurious relationships between research productivity and the independent variables. Pre-doctoral publication refers to the number of peer-reviewed journal papers published within the scientists' doctoral training periods and proves to be a significant predictor for scientists' future productivity [35]. PhD age is incorporated to account for cohort effect, as does the lapse time defined as the time span from bachelor to completion of the doctoral program.

The highly uneven distribution of women scientists across disciplines has been observed and well documented. The study uses biology as a reference group, and controls engineering, physical sciences and computer and math. The number of articles published in the first three years is not normally distributed, as is the case in any other productivity studies [36, 37], negative binomial regression is deployed for our research purpose.

IV. FINDINGS

Table 1 presents the descriptive statistics of variables of interest. The correlation analysis (not shown) suggests that those older scientists are less likely to report their earlier research outcomes. As such, the resultant sample contains more female than male scientists, reflecting to some extent the fact that female scientists disproportionally cluster in junior positions.

On average, scientists produced 4.43 articles in their early career, but male scientists outnumbered their female counterparts when disaggregated the mean articles by gender. The gender gap in this early period is consistent with previous findings [38], and is statistically significant. About half scientists had ever taken a postdoc training, and male scientists showed a

Table 1. Descriptive statistics of study variables

Variables	All (388)	Male (167)	t-test	Female (221)
Publications	4.43 (3.41)	4.92 (3.42)	**	4.06 (3.37)
Postdoc	.52 (.50)	.57 (.50)	*	.48 (.50)
Pre-doctoral publication	2.77 (3.86)	2.99 (3.97)		2.61 (3.78)
PhD prestige	2.41 (1.02)	2.41 (.99)		2.41 (1.04)
PhD age	30.0 (4.13)	29.7 (3.80)		30.21 (4.36)
Lapse time	7.49 (3.39)	7.10 (2.96)	**	7.79 (3.66)
Foreign born	.25 (.44)	.02 (.03)	*	.22 (.02)
Engineering	.49 (.50)	.49 (.50)		.49 (.50)
Physical	.26 (.44)	.27 (.45)		.24 (.43)
computer	.17 (.38)	.17 (.37)		.17 (.38)
Biology	.09 (.28)	.08 (.02)		.09 (.02)

* P<.10 ** p<0.05, *

slightly higher likelihood of postdoc training participation than female peers. Regarding the number of articles published during doctoral training, male scientists on average published 2.99 articles versus 2.61 by female scientists, however, the gender differences in pre-doctoral productivity does not reach a significance level due to the wide variations. Most scientists were selected from highly prestigious departments. In general, scientists obtained their doctoral degrees around their 30s, however female scientists tended to have a longer period finishing their doctoral training. The longer period may reflect the fact that women scientists are more interfered by marriage and family obligations than male peers [10].

To investigate how these variables can be transformed to shape scientists' research productivity, a negative binomial model was run with all above-described variables. The outcomes for two models are presented in Table 2. Postdoc training indeed boosts individual scientists' productivity. Having a postdoc training increases the expected number of articles by a factor of .15, holding all other variables constant. Being male is associated with a 16 percent higher likelihood of publishing more articles. While the gender gap has been entrenched into the literature, only very recently has the impact of postdoc training on scientists' productivity received empirical tests. This study provides such an affirmative test. It is not surprising to discover a positive impact of pre-

[c] There are scientists who received their doctoral training outside of the United States and obtained an academic position in research extensive universities. Given that the number of these scientists is quite small and their productivity pattern is seemingly different, this study excludes them.

doctoral productivity on subsequent productivity, and a one standard deviation increase in their pre-doctoral publications leads to 33 percent increase in the number of publications within the first three years at the early career stage. Other selective variables do not show significance in shaping scientists' productivity. This finding is not to deny their importance as indicated in previous studies, but suggests that the highly selective nature of academic hiring has produced a relatively homogenous elite group, therefore their impacts can be more detectable in studying selection process rather than in post-selection process.

Model 2 adds the interaction term between postdoc training and gender to test whether the gender gap in postdoc training has any influence on academic scientists' productivity. The results fail to provide support that postdoc training plays biased roles against women scientists. While both postdoc experiences and gender remain their influences on scientists' productivity in their early career periods, their effects do not shrink significantly after adding the interaction term. There is no evidence that postdoc training may give either gender an edge in producing more articles. Though male scientists seem to have a higher postdoc participation rate than female peers, this difference was not reflected in academic scientists' productivity levels.

IV. DISCUSSION AND CONCLUSION

The study investigates how postdoc training shapes academic scientists' research productivity in their first three years after the receipt of doctoral degrees, and whether the impact varies across the gender line. It is reiterated here that the study does not address whether women scientists had accumulated disadvantages when they move up through the pipeline up to postdoc training and academic employment, an issue that has been supported by extensive literature [39] . Rather, attention is cast upon scientists who had survived the pipeline and obtained an academic position in research universities. The interpretation of research findings therefore merits special caution.

Table 2. Negative binomial regression on scientists' productivity

Number of publications	Exp (β)	SE	Exp (β)	SE
Postdoc training	1.15	.07 *	1.15	.07 *
Gender	1.16	.06**	1.22	.08**
Postdoc * gender			.98	.01
Quality of PhD training	1.02	.03	1.02	.03
Pre-doctor publication	1.07	.01**	1.08	.01**
Phd age	.98	.01	.98	.01
Lapse time	.98	.02	.98	.02
Foreign	1.01	.07	1.01	.07
Computer	.79	.14*	.80	.14
Engineering	.90	.12	.91	.12
Physical sciences	.90	.12	.91	.12
-2 log likelihood	1760.12		1758.80	

$\chi^2(10)$: 118.39. * P<.10 ** p<0.05

The findings confirm that postdoc training does boost individual scientists' productivity in their early career period, and that the impact of postdoc training on research productivity does not vary across gender. That is to say, when women scientists succeed in academic employment, they indeed reaped comparable benefits from postdoc training as male counterparts in terms of productivity.

This finding does not suggest that women scientists have achieved equal status as their male counterparts in productivity. They still produce less, and consequently suffer a lot in their career advancement. Two scenarios may be possible interpretations. Academic hiring as a selective process, within which gender and postdoc training may play substantial roles, results in a highly homogenous elite group, and accordingly eases the sex differences in benefits from postdoc training. Evidence for this scenario could be found in the characteristics of scientists' doctoral training. Except their PhD age, there were no significant sexual differences in sample scientists regarding their pre-doctoral publications, and departmental prestige of doctoral training. However, reasonable doubts still exist. Usually, women scientists encounter a stricter selective process than male scientists. Given that academic departments give preference in their hiring to individuals with postdoc training, women would at least be close to, if not higher than, men scientists in postdoc participation rate. In the study, only 48% female, in relative to 57% male scientists, engaged in postdoc training. More studies are urged to unfold how the selection process, especially at the stage of academic employment, shapes scientists' career outcomes such as research productivity .

A relevant scenario rests on the accumulative advantage theory. As suggested by Reskin [40], the postdoc fellowship for male chemists are associated with high-status positions and scientific productivity, as predicted by the accumulative advantage theory; however, the female chemists accumulated no advantages with respect to the postdoc experience. The governing structure in the science community proves not to comply with the universalistic model as advocated by Merton [41], but allows multiple factors, including ascriptive factors, to play significant roles [10].If this theory is the case, the postdoc training seemingly plays neutral roles in determining individual productivity, and does not aid women scientists to catch up their male peers. Future studies are required to uncover the predictive power of this interpretation.

Both scenarios could be possible, and extant literature fails to provide evidence for/against either one. Therefore, it is too early to claim the victory that postdoc training plays equally for both sexes in terms of productivity. However, the study indeed suggests that in the academic production process, the lower productivity levels attached to women scientists can not be attributed to the presence (or lack of) postdoc training.

The policy implications of research findings are not altogether straightforward, but instructive. The study lacks the ability to answer whether or not more postdoc programs targeted women doctorates help to enhance their productivity up to the same level as male scientists, though more such programs certainly aid women scientists to produce more.

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