Academic Outcomes among Principal Investigators, Co-Principal Investigators, and non-PI Researchers

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Abstract: Faculty at research universities are evaluated on a number of productivity measures including their ability to conduct research, teach, and engage in service. Research outcomes include publishing research results and acquiring grants and contracts to conduct additional research. While it is assumed that researchers who are awarded grants are more likely to publish research results, there is little research investigating the ways in which grants affect outcomes or how principal investigators differ from researchers who do not hold research grants or those who are co-principal investigators. This research seeks to understand if principal investigators are more or less productive than co-principal investigators and those who do not have grants, and if so, what explains that variation in productivity. It also examines whether women PIs are more or less productive than men PIs. This research uses longitudinal data drawn from an NSF funded survey of academic scientists in Carnegie-designated Research I universities in six fields: biology, chemistry, computer science, earth and atmospheric sciences, electrical engineering, and physics. From this national random sample of men and women scientists and engineers we investigate whether there is variation in the production of outcomes (e.g. publications, teaching, and training graduate students) among PIs, Co-PIs, and other researchers. Findings show that productivity and outcomes vary significantly for PIs, co-PIs and by sex.

I. Introduction

Productivity outcomes in research universities in the United States have long been organized into three categories: research, teaching, and service. Research is typically measured by peer-reviewed journal publications, conference presentations and proceedings, book chapters, books, and other forms of publication. Publications are important indicators of science productivity because they indicate dissemination and verification of findings by peers (Price 1963; Merton 1973). Publication metrics include not only publication counts, but also publication quality, which is often measured as citation rates. Research grants are another important indicator of science productivity. Because most grants are awarded through a competitive, peer-review process, universities view grant awards to be endorsements of the quality and value of new research ideas. In addition to bringing in revenue to the university to support research, purchase and maintain research equipment, update facilities, and further training of graduate students, grant awards have the potential to advance the reputation of the scientist and the university. The other categories of productivity outcomes – teaching and service – are important albeit often less renown in research universities. Teaching is usually measured as the number and type of courses taught, and assessed using student evaluations of the instructor. Training and mentoring of graduate students are also important, albeit often ignored, activities within the teaching category. Service activities include service to students (e.g. advising and mentoring), department (e.g. committees), campus (e.g. committees and administrative work), community (e.g. media appearances, expert testimonies), and discipline (e.g. leadership in scientific associations).

While there is some evidence that activities across these three categories or roles – research, teaching, and service – are complimentary (Becker 1975; Colbeck 1998; Faia 1980; Marks 1977), others find they are substitutive such that, for example, faculty who focus on research and publishing commit less of their time to teaching and service (Coser & Coser 1974; Goode 1960; Hu & Gill 2000). Some work has shown that faculty spend about 20 percent of their time on activities that simultaneously accomplish teaching and research goals (Colbeck 1998) or that 22 percent of faculty in four year institutions attained high productivity in both teaching and research (Fairweather 2002). However, there has been little to no empirical research investigating how different within-category activities affect each other. For example, it is unclear whether grant awards are associated with higher or lower production of journal articles, or whether grant success increases or decreases teaching and graduate student training. In response, this research examines how grant awards advance or hinder publication, teaching and training outputs of academic scientists.

This research empirically tests several basic assumptions about the relationships between grant-getting and other forms of productivity in academic science. Specifically, we investigate whether being a principal investigator or co-principal investigator is related to increased academic outputs, measured as publications, teaching, and supervision of research assistants. We also examine whether the relationships between grant-getting and productivity outputs are similar for men and women. We are particularly interested in the potential differential effects of principal and co-principal investigator roles on different outputs. This paper addresses the following research questions: Do principal and co-principal investigators produce more journal articles than faculty who do not have grants? Does being a principal or co-principal investigator differently affect other activities such as teaching loads and training of graduate students? Is the productivity of men and women scientists similarly affected by grant awards?

The paper first examines what is known about the role of principal and co-principal investigators before developing hypotheses about the relationships between being a PI and publishing journal articles, teaching, and supervising research assistants. We also develop a hypothesis to examine whether grant-getting differently affects outcomes for women and men. Hypotheses are tested using survey data collected from scientists at two points in time, 2007 and 2010. The longitudinal nature of the data allows us to examine how having grants in time one affects production outcomes in time two. We conclude with a discussion of the implications for national grant policy and for management of university incentives for multiple production outcomes.

II. Principal and Co-Principal Investigators

The conduct of science is increasingly a team-based activity in which multiple investigators collaborate to advance knowledge (Lee & Bozeman 2000; Hackett 1990). Much of this team-based work is funded through federal research grants with team members taking on particular roles such as PI, co-PI, researchers, consultant, or student research. Within this context, PIs and co-PIs are the key personnel that oversee grant money, conduct research, train students, hire research personnel, and carry out numerous decisions that affect the conduct of science. They integrate funder incentives and university regulations in the development of research activities and outputs. For example, a PI might choose to employ undergraduate researchers on a project because federal funders encourage research universities to engage undergraduates in the research process. PIs and co-PIs from different disciplines or institutions may choose to collaborate in response to funder priorities (Abramo et al. 2009), further emphasizing the important role that funded research has on shaping research agendas and collaborative networks. Given the large influence that PIs and co-PIs have over the conduct of and advancement of science, it is increasingly important to understand how these roles matter within the broader work context of academic science and engineering and the production of outcomes.

The distinction between principal and co-principal investigator is not always clear. For example, the NSF has consistently defined principal investigator/project director (PI/PD) as “the individual designated by the grantee and approved by NSF, who will be responsible for the scientific or technical direction of the project. If more than one, the first one listed will have primary responsibility for the project and the submission of reports. All others listed are considered co-PI/PD, and share in the responsibility of the scientific or technical direction of the project” (NSF 2011, Introduction D, 1, h). In 2008, the NSF further refined its perspective on the distinction between PI and co-PI noting that “NSF does not infer any distinction in scientific stature among multiple PIs, whether referred to as PI or co-PI. If more than one, the first one listed will serve as the contact PI, with whom all communications between NSF program officials and the project relating to the scientific, technical, and budgetary aspects of the project should take place. The PI and any identified co-PIs, however, will be jointly responsible for submission of the requisite project reports.” (Federal Grants News 2008; NSF 2011, II-40). The principal investigator is both administrative and intellectual leader in the first instance, but administrative leader and intellectual peer in the other.

While the principal investigator is commonly recognized to be the lead of the research project (Fields & Price, 1993; Morahan & Feetwood, 2008) or team leader (Hackett 1990), the role of the PI may differ depending upon the project. In some cases the PI may be the actual intellectual leader, in other cases the PI might be the person that the team determines is the most likely to receive the award, based on subjective assessments of prestige, reputation, and qualifications. To enhance the probability of obtaining an award, junior researchers that generate proposal ideas may take a formal role as co-PI or research personnel, while a more experienced or better-known faculty member may serve as the PI. Alternatively, junior, less experienced researchers might take on a PI role to take advantage of set aside funds for new or beginning researchers. For example, the NSF now asks researchers to indicate if the PI is a "beginning investigator", defined by the NSF as someone who has not held a federally funded award with the exception of doctoral dissertation, postdoctoral fellowship, or research planning grants. Other agencies, including the Office of Naval Research, National Institutes of Health, and the National Institute for Food and Agriculture, offer new and young investigator awards. In these cases, the research team might be responding to the funder's desire to support new investigators, selecting the less experienced researchers to serve as the PI. In sum, the assignment of the title PI or co-PI might indicate differing roles on a project or be assigned in response to funder priorities or strategies in grant competitions. Despite these possible arrangements, the PI role is widely recognized to be more prominent, more responsible, and more in charge of a funded project than the co-PI role.

III. Linking PI and co-PI Status to Publications, Teaching, and Training

In seeking to understand why PIs and co-PIs may produce more or fewer outputs, there are two theoretical approaches commonly used to explain productivity outcomes in academic science: cumulative advantage and social role theory. First, cumulative advantage posits that success in science results from feedback from recognition, resources, and productivity. Structural advantages, such as graduation from a prestigious department, strong research training, and early career mentoring provide initial advantages that lead to access to resources important for the conduct of research. Subsequent research outputs such as publications receive formal and informal feedback that ultimately results in increased future recognition, resources, and productivity, and so on (Bentley & Blackburn 1990; Creswell 1985; Creamer & McGuire 1998; Cole & Zuckerman 1984; Fox 1983).

As scientists are increasingly required to obtain grants at earlier stages of their careers, the value of utilizing cumulative advantage to demonstrate the potential becomes more important. Indeed, Hackett (1990) finds that institutional tenure and promotion requirements increasingly require faculty to obtain external funding. As institutional funding continues to disappear, grant funding is an important source of revenue for scientists to support students and ongoing research and to demonstrate immediate and future potential value to the department and university. In addition to providing funds for conducting research and training students, grant-funded research can expand a scientist's opportunities for gathering data, expanding collaboration networks, and thus increasing productivity. Cumulative advantage theory leads to the expectation that obtaining a PI or co-PI grant represents initial access to resources that would then be transformed into publications, and eventually greater recognition and future resources.

Social role theory provides the second rationale for understanding how the various roles of academic faculty – researcher, mentor, teacher, committee member, and administrator – interact in ways that complicate or facilitate productive science. Faculty have a finite amount of time to allocate to various roles. Prior work has shown that while there is some complementarity across different teaching and research roles, it is limited (Colbeck 1998). Fairweather (2002) finds only a slight "spillover effect" between teaching and research and Ramsden (1994) shows that commitment to teaching at both the individual and department levels lowers research activity. Hu and Gill (2000) find that once faculty members teach more than eleven hours per week there begins a strong negative relationship between teaching and research productivity. Similarly, Mitchell and Rebne (1995) find that the first eight hours of weekly teaching has a positive effect on research activity, but more than eight has a negative effect on publication outputs. In general, most research shows some level of role conflict between teaching and research such that a higher level of teaching ultimately leads to reduced research activity.

When scientists and engineers receive grant awards that call for substantial new research activity, role conflict can increase. One way in which the department and university can alleviate this role conflict is to allow the awardee to substitute research workload for teaching workload. Given the tensions between the roles of teaching and research, it follows that when departments and universities alleviate this tension by allowing faculty to use grant funds to reduce teaching loads or "buy-out" of course teaching, faculty will continue to seek funding for their research activities. While, it is clear that enactment of multiple roles can result in conflicts that reduce productivity, the level of conflict probably varies depending upon the roles considered and the extent to which department and university workload policies address these conflicts.

Prior research has not examined whether being a PI or co-PI is related to productivity. However, we can apply both cumulative advantage and social role theories to develop a model of the expected relationships. In addition, we assume that departments and universities are likely to attempt to maximize production of outputs that enhance their own stature and reputation. Because departments and universities are socially negotiated institutional environments in which some accommodation of workloads and work roles can be made (Colbeck, 1990), we would expect that departments and universities will adopt workload policies that further enable grant income and research production (Hackett, 1990), and simultaneously reduce role conflict. While we cannot observe department and university policies, we expect that on average PIs and co-PIs will receive reduced teaching loads either because the 'buy-out' teaching effort or because of some other negotiated agreement for course release.

H1: Having grants will be associated with higher numbers of publications.
H2: Having grants will be associated with a lower teaching load.

While the role overlap between teaching, research, and administration may be limited, the role overlap between research and training of graduate students may be greater. In academic science and engineering, the increasing dependency upon funded research projects for support of graduate students has resulted in a proliferation of graduate assistantships (Hackett 1990). That said, graduate students might have positive and negative impacts on the productivity of the grantee (Wood 1990). For example, if mentoring and training duties were high, we would expect a negative impact, at least in the short-run, on awardee productivity. However, if graduate assistants are strongly motivated and have high capacity and independence, they may increase the productivity of the PI or co-PI. For example, highly productive graduate research assistants might increase the number of publications co-authored with the project PI and Co-PI. Similarly, graduate students might result in increased productivity on research projects, in general.

Although grant funding is likely to increase the hiring of research assistants, there is little research investigating the relationship between working with students and research productivity. Wood (1990) notes that there is a general belief that working students can "enrich the environment through their enthusiasm and new ideas" (pg. 90), but there is also an understanding that student researchers might also overburden faculty, especially when those students are unable to carry out independent research or lack motivation. More recently, grant funders such as the NIH and NSF have made working with students an increasingly important component of grant-getting. Grant applications ask applicants to indicate the educational and training outcomes of research proposals, implicitly assuming that funded science will train future scientists. Moreover, recent calls for proposals ask applicants to include undergraduate researchers in their proposals. While no evidence exists tying PI or co-PI awards to hiring research assistants, we expect, given the trends of increasing grant dependence and funders' preference for training students on research grants, the relationship is positive. While it is possible that administrative duties (e.g. running labs, managing grants, overseeing projects) required for managing multiple funded projects may reduce faculty ability to publish research results, we expect that the positive effects of added resource and graduate student capacity will outweigh the negative effects of increased administration on productivity. Although the relationship between working with research assistants (e.g. students) and academic productivity has not been tested empirically, we expect that the shift in priority toward supporting students on funded projects will mean that PIs and co-PIs will have more graduate assistants than non-awardees, who lack the resources to independently fund research assistants.

H3: Having grants will be associated with supervising more research assistants.

It is not clear whether or not productivity output will be higher or lower for PIs as compared to co-PIs. As noted earlier, the PI role is consistently described as administrative research leader, while the co-PI is more often considered to be a team member. Hence, it is likely that there are substantial differences in the administrative requirements associated with PI awards, as compared to co-PI awards, where PIs are more responsible for management and reporting. Research indicates that grant success is associated with higher levels of administrative duties (Hackett, 1990) and the implications for grant administration on research are likely similar to findings on service load. This additional administrative burden can have strong effects on research productivity and cause role conflict. First, administrative tasks are often less valued in academia. Carr and colleagues (1993) show that faculty generally prefer to work much more on research and much less on administration than they actually do (1993). Second, additional administrative and service work is negatively related to research activity, because productivity is possibly related to the amount of time devoted to research (Hu and Gill 2000). Additionally, it is likely that administrative roles have a greater level of immediacy associated with them and are therefore prioritized over other roles, such as research productivity (Wood 1990). In sum, the administrative burden associated with managing a grant as a PI might be related to reduced time allocated to research activities such as publishing research results and training students.

On the other hand, it is also possible that PIs, as the project leads, may be more likely than co-PIs to employ graduate students due to their higher authority and administrative positions. Additionally, serving as a PI might ensure that the scientist is credited on all outputs associated with the grant, thus increasing co-authorships and publications for the PI. On the one hand, being a PI may lead to greater productivity due to higher graduate student employment and greater reach on the project; on the other hand, due to heavy administrative requirements on the PI, the PI may spend less time on research activities and publishing, leaving the co-PI better positioned to focus on research outputs.

While there is no research indicating whether the work load and roles on grants will lead PIs and co-PIs to have differing levels of academic outcomes, there is some research investigating the ways in which these two roles are valued in the academy. Faculty evaluations and departmental incentives tend to show that the role of PI is often considered to be more valuable or recognized than the role of co-PI. For example, work by Scheid and colleagues (2002) shows that a PI award carries the highest relative value of all academic products, while the relative value of a co-PI award holds about two thirds the relative value of the PI award. A co-PI award has a relative value just below that of a sole author refereed article, making combined value of a co-PI award and a journal article somewhat higher than a PI award. Hence, even in terms of cumulative advantage or local department rewards, a co-PI may be able to receive greater reputational returns than a PI. The loss in prestige and recognition from the 'reduced' co-PI role is made up by the increased production of publications. These types of trade-offs occur within the departmental and university context where incentives, workload policies, norms of social negotiation, and output valuation play out (Colbeck 1990). Because prior work on this is scant and because these workload policies are not easily observed, we offer the following hypotheses:

H4: PI awards will be related to producing more journal publications as compared to co-PI awards.
H5: PI awards will be related to decreased teaching loads as compared to co-PI awards.
H6: PI awards will be related to supervising more graduate assistants as compared to co-PI awards.

Research indicates that academic productivity is related to personal attributes (researcher sex, age, education, etc.), institutional and departmental attributes (characteristics of the institution, size of faculty, technology and instrumental infrastructures available, etc.) and environmental attributes (labor policies, public and private funds available, students available to support the research, etc.). As researchers and science funders have become increasingly concerned about the dearth of women in science, technology, engineering, and mathematics (STEM) fields an increasing amount of research has focused on comparing the productivity rates of men and women. Early research found that after controlling for rank and discipline, gender is not related to research output (Blackburn et al. 1978), however, more recent work argues that because of the structural barriers women face in the academic work place, they often have work loads and outputs that differ from men (Bain & Cummins 2000; Etzkowitz, Kemelgor, & Uzzi 2000). For example, women are more likely to have lower ranking positions and are often saddled with more teaching responsibilities than men (August & Waltman 2004). Additionally, women take on more institutional responsibilities, which may contribute to lower research productivity (Olson, Maple & Stage 1995).

A number of studies have found variation in publication rates by sex (Blackburn & Lawrence 1996; Creamer 1999; Long & Fox 1995; Prpic 2002; Zuckerman et al. 1991). For example, investigating a sample of chemists, Reskin (1978) found that men chemists produce more publications than women, but that women are more responsive to prestigious postdoctoral fellowships, employment in tenure-track university position, and collegial recognition. Fox (2005) investigated productivity of women in academic science, looking at the ways in which marriage and having children are related to women's productivity. Fox concludes that women with preschool children have higher productivity than women without children or with school-age children. She also finds that women's productivity rates vary based on their marital status and type of marriage (e.g. first marriage, marriage to an academic scientists), concluding that productivity for women scientists is complexly related to marital status, having children, and type of marriage and that these relationships are different for women and men.

While there is a great deal of research investigating science outcomes and comparing research outcomes of men and women, there is no previous research investigating the ways in which grant-getting differently affects outcomes for men and women academic scientists. Given the previous work finding significant variation in science careers and outcomes for men and women, we propose the following hypothesis:

H7: The relationship between grants and work outcomes will be significantly related to sex.

IV. Data and Models

This analysis uses data from national surveys of academic scientists and engineers in Research I universities in the United States collected at two points in time. The surveys collected data on individual background, career experiences, research and teaching responsibilities, productivity, satisfaction, and professional networks. The surveys were implemented online using Sawtooth Software®. Individuals were invited to the survey via traditional mail with a series of personalized email follow-ups. Each of the invitations provided individually assigned user-id and password and directed the individual to the survey website. Overall, the survey took between 30 and 45 minutes to complete.

The first survey was administered in 2007 to a random sample of 3,667 participants stratified by sex, rank, and discipline from the population of academic scientists and engineers in six disciplines in Carnegie-designated Research I universities (150 universities). The population was constructed by manually retrieving information from the web sites of the relevant departments or university directories, and copying the faculty information for assistant, associate, and full professors (all of which indicate rank). The disciplines (biological sciences, chemistry, computer science, earth and atmospheric sciences, electrical engineering, and physics) were selected based on the level of female representation (low, transitioning, and high fields). Of the 1,774 completed surveys, 176 were removed because of ineligible rank, or discipline. Also, 21 partially completed surveys were deemed to have sufficient information (over 95% of questions answered) and included. The final analysis sample size was therefore 1,598 surveys. The overall response rate of the survey, calculated using the RR2 method of the American Association for Public Opinion Research (AAPOR) was 45.8%. The weighted response rate was 43% (AAPOR 2009).

The second survey was conducted in 2010. The purpose of this second survey was to gather longitudinal data from respondents of the 2007 survey. Much of the content of the 2010 survey was identical to that of the first survey, enabling the examination of change in the respondent's network, research activities, and outcomes. The population for the second survey was derived from the 1598 respondents of the 2007 Phase I survey. The final sample size of the 2010 survey was 1498, after eliminating 100 respondents that had invalid email addresses. The overall response rate of the 2010 survey, calculated using the RR2 method of the American Association for Public Opinion Research (AAPOR) was 51% (weighted response rate was also 51%). The number of complete responses was 765. Responses were fairly evenly distributed across gender (48% women) and field (19% from biology, 19% from chemistry, 15% from computer science, 19% from earth and atmospheric sciences, and 12% from electrical engineering). The distribution of rank is nearly proportionate to the population (27% assistant professor, 27% associate professor).

Dependent Variables: We use three dependent variables to capture faculty outcomes in Time 1 (2005-2007): publications, teaching, and research assistants. **Publications** is a self-reported measure in response to the following questionnaire item: Please indicate how many peer reviewed academic publications (accepted or published) you had in the past two academic years (2005-2007). Response categories are the following categories: 0, 1-2,3-4, 5-6, 7-9, 10-14, and 15 or more. **Teaching** is the number of courses that the respondent taught or co-taught in past academic year (2005-06). Teaching is a categorical variable with the following categories: 0, 1, 2, 3, 4, and 5 or more. **Research Assistants** is a categorical variable indicating the number of research assistants that the respondents supervised in past academic year (2005-06). Response categories are 0, 1, 2, 3, 4, and 5 or more.

After examining the immediate effects between having grants and outcomes, we examine the medium term effects on outcomes in Time 2, 2007-2009. We have two dependent variables for time 2: **PublicationsT2** and **TeachingT2**. **PublicationsT2** is a categorical variable indicating the number of journal publications from 2007 through 2009. **TeachingT2** is a categorical variable indicating the number of courses that the respondent taught or co-taught in past academic year (2008-09). The response categories in Time 2 are the same as for Time 1.

Independent Variables: The primary independent variables of interest are whether or not the respondents are Principal Investigators (PI), Co-Principal Investigators (co-PIs), and gender. We use four mutually exclusive dummy variables to capture the respondents' status on grants. These four variables were created using responses to the following two questionnaire items: "In the last 2 years of the PI grants you submitted, how many were successful?" and "In the last 2 years of the co-PI grants submitted, how many were successful?" We then created variables for all respondents indicating if they had successfully been awarded grants for which they were a PI or Co-PI. The variable, **PIonly** is coded one if the respondent received at least one grant as a PI between 2005-2007. **Co-PIonly** is coded one if the respondent received a co -PI on at least one grant from 2005-2007. **BothPIorCo-PI** is coded one if the respondent received PI and co -PI grants from 2005-07. **NeitherPInorCo-PI** is coded one if the respondent did not receive a PI or co-PI grant from 2005-07. In this sample, 404 individuals received grants as PIs during 2005-07, 122 received grants as co-PIs, 547 received both PI and co-PI grants, and 231 did not receive an award as either PI nor a Co-PI. Gender is measured with a dummy variable, **Female** (=1). As a result of over sampling, there are 731 women (45.7%) in the sample.

Controls: Previous research has found that productivity is related to institutional and environmental factors such as discipline and faculty size (Dundar & Lewis 1998), prestige of the academic position and context (Long & McGinnis 1981), and personal factors such as sex, age, and education, scientific collaboration (Fox 1983, 1992 a,b; Lee & Bozeman 2005; Reskin 1978). In order to assess the relationships between being a principal investigator or co-principal investigator and academic outcomes, it is important to control for a number of these factors. First, we control for the field of science using the following dummy variables: **Biology, Chemistry, Computer Science, Earth and Atmospheric Science, Electrical Engineering,** and **Physics.**

Since research indicates that affiliation with research centers may be related to productivity (Ponomariov & Boardman 2010), we control for whether or not the respondent has a formal affiliation with a research lab or center. The variable, **Lab Affiliation**, is coded one if the respondent has a formal affiliation with a research lab or center. Approximately one fifth of the respondents report having a lab or center affiliation.

We also control for seniority and rank with a series of variables.[1] First, we measure time in the career with the continuous variable, **TimeSincePhD**, which ranges from one year to 54 years with a mean of 18.5 years. Second, we include a dummy variable, **Tenured**, which is coded one if the respondent has tenure; 1105 individuals in the sample have tenure. Because previous research indicates that senior professors are likely to have heavier service loads than junior faculty (Hu & Gill 2000), while women are also more likely to be junior and have higher teaching loads than more senior, men faculty (August & Waltman 2004), it is important to control for rank. Academic rank is measured with three dummy variables for **Assistant Professor** (=1), **Associate Professor** (=1), and **Full Professor** (=1). **Age** is a continuous variable, with a range of 28 to 82 and mean of 48. Finally, we control for the total dollar amount of grants received by the respondents, since it is possible that an individual is a PI or Co-PI, but does not have a large enough grant to purchase course-buyouts or hire research assistants. We asked respondents to report the total dollar amount of all successful grants for which they are listed as a PI or Co-PI from 2005 to 2007. **TotalGrants2005-07** is a continuous variable ranging from zero to 154 million, with a mean of 1.868 million.

We conduct two sets of OLS regression estimations. The first set of estimations uses the Time 1 dependent variables of publishing, teaching, and the number of research assistants. The second set regresses the Time 2 dependent variables on the independent and control variables. We conduct these two different estimations, because it is possible that being awarded a grant that was submitted during the two years prior to the survey may have both immediate and longer-term effects. Although the near term effects are likely to result in immediate changes in teaching and supervised graduate assistants, we also examine publication outcomes at Time 1. In the medium term, we expect the cumulative effects of receiving a grant may have continuing effects on teaching and publication outcomes. Descriptive statistics for all variables are noted in Table I.

[Insert table I about here]

[1] Although each of these measures capture rank and seniority and would be expected to be related to age, a multicollinearity test indicates that the and age

V. Results

Before running the full regression models, we conducted a crosstabulation to investigate differences in outcomes across the four groups of interest in Time 1. Table II compares the mean responses for PIs, Co-PIs, respondents who are both PIs and co-PIs, and those who are neither. Looking at publications, we see that those who received grants as both PI and co-PI report a mean response of 4.39, where 4 indicates 5-6 publications per year and 5 is 7-9 publications per year. Those with no grants report the lowest mean of total publications. Those who are both PIs and co-PIs report the highest mean of supervising research assistants, with a mean of 4.26, while those who are neither PIs nor co-PIs report supervising an average of 2.8 research assistants. When we look at teaching loads, we see that respondents who have no grants report the highest mean teaching load (3.63), followed by PIs (3.58), and then co-PIs (3.42). Respondents who are both PIs and co-PIs report the lowest mean teaching load (3.37).

[Insert Table II about here]

The differences in means and responses for each of the four groups and the three outcome variables, publications, teaching, and research assistants are statistically significant. The Chi square indicates that the variance is significant at the 0.000 level for all of the groups. In sum, the differences in mean production of publications, mean teaching loads, and the mean number of research assistants supervised are significantly different for PIs, co-PIs, those who are both PIs and co-PIs, and those who did not receive grants.

[Insert table III about here]

Table III presents the results of the regression analyses predicting publications, teaching, and research assistants in Time 1 for principal investigators, co-principal investigators, and those who are both PIs and co-PIs. We see that when controlling for gender, field of science, lab affiliation, rank, age, and amount of grant awards, outcomes vary significantly between those who have grants and those who do not. Specifically, we find strong support for the first hypothesis that having grants is associated with higher numbers of publications. PIs, co-PIs, and respondents who are both report significantly more publications than those who do not have grants. We also find support for the second hypothesis that having grants is associated with a lower teaching load, though this relationship only holds for those who are PIs and both PIs and co-PIs. We do not find a significant relationship between being a co-PI and having a reduced teaching load. Similarly, we find partial support for H3: Having grants will be associated with supervising more research assistants. Faculty who are PIs or who are both PIs and co-PIs supervise significantly more research assistants than those who do not have grants. However, receiving a co-PI grant does not affect the number of supervised research assistants reported by respondents.

Having found support for the first three hypotheses which predicted relationships between having grants and increased publications, reduced teaching loads, and increased supervision of research assistants, we now turn to the second set of hypotheses which addressed differences between PIs and co-PIs. First, we see that Principal Investigators, compared to those who received no grants, produce more publications, supervise more research assistants, and teach fewer courses in Time 1. The direction of these relationships hold for faculty who are both PIs and co-PIs on grants from 2005-07, but the magnitude of difference is stronger for those who are both PIs and co-PIs as compared to those who are PIs alone. Thus, faculty who are both PIs and co-PIs have higher near-term production of publications, lighter teaching loads, and supervise more research assistants than those who are PIs alone.

Interestingly, we see that outcomes are slightly different for co-principal investigators. Co-PIs produce significantly more publications than those who do not have grants, but do not significantly vary in the other two outcomes (teaching and research assistants). Co-PIs, compared to those with no grants, produce significantly more publications, but this production is lower than that of PIs. We find support for H4 that PI awards are related to producing more journal articles than co-PI awards. We also find support for H5 and H6, which predicted, respectively, that PIs would have lower leaching loads and supervise more research assistants than co-PIs.

The results presented in table III indicate the ways in which sex is related to the three outcomes in Time 1. Women produce significantly fewer journal publications, teach significantly fewer courses, and supervise significantly more research assistants than men. Because we are interested in understanding the ways in which grant getting is related to outcomes and how those relationships might differ for men and women, we split the sample by sex and ran separate models for men and women. Table IV presents the results for those models and shows how the independent variables in the models differently affect outcomes for men and women.

[Insert table IV about here]

Table IV indicates support for our seventh hypothesis that the relationships between grant getting and outcomes (publishing, teaching, and supervising research assistants) are significantly related to sex. For example, we see that the relationships between grant getting and outcomes significantly vary for men and women in Time 1. For women there is no significant relationship between being a PI and publishing, but for men, being a PI is significantly related to increased publishing outcomes. We also see that among co-PIs, publishing outcomes vary for men and women. Women co-PIs report significantly fewer publications as compared to women with no grants. Whereas, men co-PIs report significantly more publications as compared to men with no grants. We also see that receiving both PI and co-PI grants is related to a significant increase in publishing outcomes for men and for women.

When we consider teaching outcomes in Time 1, we see men who are PIs and men who are both PIs and co-PIs report lower teaching loads than men who do not have grants. In contrast, being a PI or both PI and co-PI, for women, is not significantly related to teaching loads. Rather, women who are co-PIs report higher teaching loads than women who do not have grants. Thus, grant getting for women is either not related to near term teaching loads or actually increases teaching loads, while grant getting has the reverse effect for men.

Finally, we see that the relationships between grant getting and supporting research assistants in Time 1 are consistent for men and women, though the magnitude of the relationships differ. Both men and women principal investigators report supervising significantly more research assistants than those who do not have grants. Additionally, those who receive both PI and co-PI awards report supervising significantly more research assistants. The relationship between receiving both PI and co-PI awards and having research assistants is stronger for men than women. There is no significant relationship between being a co-PI and supervising research assistants. This might be explained by the fact that PIs generally have the authority to hire students.

The analyses presented in Tables III and IV present strong evidence that grant-getting is related to near-term work outcomes for academic faculty. Specifically, we find support for H1, and find that having grants is significantly associated with increased publication rates. This relationship holds for men, but as noted in Table IV, there is a negative relationship between being a co-PI and publication productivity for women. We find strong support for H2, having grants is associated with lower teaching rates. Though again, we find this is consistently true for men, but women co-PIs report increased teaching loads. Finally, we find support for H3 and conclude that being a PI (or both a PI and co-PI) is positively related to supervising more research assistants. While these findings are useful, they are limited by the cross-sectional nature of the data. Thus, we turn to the results of the longitudinal analysis, presented in Tables V and VI.

[Insert table V about here]

Table V shows the results for predicting publications and teaching loads for faculty in Time 2. Again, we find strong support for both H1 and H2. Having grants, as compared to not having grants, significantly increases publishing for academic faculty and significantly decreases teaching loads. The relationship between having grants and increased publishing is strongest for faculty who are co-PIs, followed by those who are co-PIs and PIs, and then faculty who are Principal Investigators alone. It appears that having a co-PI role might be more advantageous for producing publications. The relationship between grant getting and teaching loads also varies across PIs, co-PIs, and those who are both PIs and co-PIs. Faculty who are both PIs and co-PIs report the largest reductions in teaching loads, followed by PIs, and then co-PIs.

Overall, we see that grant getting provides the resources and support to enable faculty to increase journal productivity and relieve them of teaching. Taken together, the variation in magnitude of relationships for PIs, co-PIs, and faculty who are both PIs and co-PIs, it seems that for co-PIs grants offer additional support and resources for increased publication production, while for PIs grant funding provides additional support for course buy-outs.

Similar to the analysis of men and women presented in Time 1, estimations show that grant getting the effects on work outcomes in Time 2 vary for men and women respondents. Table VI shows the causal relationships between grant getting and publishing rates and teaching loads for women and men faculty. Importantly, we see that at Time 2 the relationships between grant getting and publishing for women change from Time 1. In Time 2, having grants is a consistent significant, positive predictor for publishing for women. Also, women faculty who are both PIs and co-PIs report the highest publishing outcomes, followed by co-PIs, and then PIs (note that in Time 1, the relationship between women co-PIs and publishing was negative and the relationship between women PIs and publishing was not significant). The literature has found that women tend to produce less than men (Etzkowitz 2002), which is confirmed in our Time 1 results. Perhaps, receiving a grant provides the needed capacity to increase production levels; women may realize higher cumulative benefits than men as a result of receiving grant awards. Additionally, the magnitude of the relationship between grant-getting and publishing outcomes for women is larger than for men. In fact, the constant and in some cases the Beta coefficients for women are nearly twice that of the model predicting publishing outcomes for men. In sum, we see that having grants results in clear positive publishing outcomes for women scientists, as compared to not having grants.

[Insert table VI about here]

When we look at teaching loads in Time 2, we see that having grants is a significant predictor of having a reduced teaching load for both men and women. Women who are PIs and women who are both PIs and co-PIs have significantly lower teaching loads as compared to those who do not have grants. However, for women there is not a significant relationship between being a co-PI and teaching loads; for men, having any role on a grant (PI, Co-PI, or both) results in a reduced teaching load.

In sum, grants play an important role in increasing work outcomes for women, especially when looking at the downstream, or cumulative benefits. In fact, being a PI or a co-PI increases publishing outcomes for women. However, when we consider the limited amount of time faculty have to dedicate to publishing, managing grants, overseeing students, and teaching, it is important to note that for women, being a PI (or both PI and co-PI) reduces teaching loads, but being a co-PI alone does not significantly reduce teaching loads.

VI. Concluding Discussion

This research is a first step at understanding the effects of grant getting on faculty outcomes. Moreover, this is the first study to look at how grant-getting differently affects outcomes for faculty in different roles: PIs, co-PIs, and those who are both PIs and co-PIs. Overall, we find that having grants is significantly related to increased research outcomes for academic faculty in STEM fields at Research I universities. Faculty who have grants produce significantly more journal publications and supervise more research assistants than those who do not have grants. We also find that there are distinctions between roles on grants; principal investigators report significantly different outcomes than co- Principal Investigators.

Before discussion the policy implications of these findings, it is important to note the limitations of this study. First, this study relies on self-reported survey data. All outcomes (e.g. publication production, teaching loads, and supervising research assistants) are self-reported and subject to respondent recall. Second, this research is limited to faculty working at Research I universities in six fields of science: non-medical biology, chemistry, computer science, earth and atmospheric sciences, electrical engineering, and physics. Therefore, care should be taken when generalizing these results to faculty at other types of universities, faculty in other STEM fields, and faculty in the humanities and social sciences. Finally, as with all social science research, there are concerns about the direction of causality. It is possible that the relationships we find in the first set of regressions are picking up associations between grant getting and outcomes, not causal relationships. However, our use of data from two time periods does enable us to more firmly establish the causal relationships between our dependent and independent variables.

Despite the limitations of this research, the findings are important for faculty, universities, and policy-makers. This research produces three overall important findings: (1) having grants is associated with increased academic outcomes, (2) PIs and co-PIs have distinct outcomes from grants, and (3) grant-getting differently affects outcomes for men and women scientists.

First, we find that having grants is related to increased faculty outcomes. Faculty who have grants publish more and supervise more research assistants than those without grants. We also see that grant-getting enables some level of substitution when it comes to balancing the faculty roles of conducting research, publishing, and teaching, with grant-getting being associated with reduced teaching loads. Thus, faculty priorities and university priorities seem to align when we consider grant-getting and outcomes.

Second, we find that the roles of principal investigators and co-principal investigators are significantly distinct in the production of outcomes. In general, principal investigators publish more, teach less, and supervise more research assistants than co-principal investigators. While this research does not investigate the different roles that PIs and co-PIs play in managing and administering a grant, it does indicate that research outcomes vary for these two roles. As the primary administrator on the grant, PIs appear to take more responsibility for supervising research assistants and benefit more from course releases. However, co-PIs still report increased publications and reduced teaching loads in comparison to those who do not have grants. Future research should seek to discover the nuances between PI and co-PI roles on grants and how those roles are more directly related to work outcomes.

Third, we find that the relationships between having grants and productivity vary significantly by sex. Even more important, we see that for women being a PI or co-PI is associated with some negative near term outcomes, but that over the longer term grant awards show cumulative benefits. Concerning the analysis of Time 1 outcomes, there is no significant relationship between receiving a PI award and publishing and teaching outcomes for women. Meanwhile there is a negative relationship for women between being a co-PI and publishing in Time 1. It seems that being a PI has better near term outcomes for men than for women. However, the Time 2 findings show women award recipients generally produce more publications and teach fewer classes, and that these results are similar to the findings for men. It is possible that the Time 1 results show that women are less likely to have established the publication returns, teaching reductions or research assistantships when they receive the grants. Possibly this is because the population of women in most fields of science and engineering studied here is more junior compared men. As a result, they are less likely to demonstrate near term benefits from awards. However, once the award is received, the downstream benefits cumulate as fast for women as they do for men.

These findings can also be explained in terms of cumulative advantage and social role theory. For example, it is possible that benefits of receiving a grant award accumulate much faster for men because men are more likely, as a population, to have a higher level of cumulative advantage. Women, as a population, have not accumulated sufficient advantage when awarded a grant, so the returns are slower. But over time, two years, the advantage of receiving a grant award tends to even out. This tends to imply that the grant award policies targeting women are critical for evening out the cumulative advantage playing field in science.

Additionally, the findings may indicate that social roles are stickier for women than for men. Whereas men are able to more quickly benefit from grant awards, in terms of lower teaching loads, more graduate assistants, and ultimately more publications, women are less able to obtain course releases and, perhaps, find it more difficult to quickly hire graduate students. It is possible that social roles are more easily negotiated in universities for men than for women, which results in slower departmental or institutional response times for women to receive the award benefits. While over time women are still able to capitalize on the awards received, it is possible that the stickiness of social roles for women reduces the speed with which they are able to attain cumulative advantages.

VII. Tables

Table I: Descriptive Statistics

Time 1 Survey Data	**N**	**Missing**	**Mean**	**Std. Dev.**	**Min**	**Max**
Principal Investigator (2005-07)	1304	294	0.31	0.46	0	1
Co-Principal Investigator (2005-07)	1304	294	0.09	0.29	0	1
Both PI and Co-PI (2005-07)	1304	294	0.42	0.49	0	1
Neither PI nor Co-PI (2005-07)	1304	294	0.18	0.38	0	1
Female	1598	0	0.46	0.50	0	1
Chemistry	1598	0	0.18	0.38	0	1
EAS	1598	0	0.16	0.37	0	1
Biology	1598	0	0.18	0.39	0	1
Physics	1598	0	0.17	0.38	0	1
Computer Science	1598	0	0.13	0.34	0	1
Electrical Engineering	1598	0	0.17	0.38	0	1
Formal affiliation with lab or center	1598	0	0.22	0.42	0	1
Time since PhD awarded	1591	7	18.51	10.43	1	54
Tenured	1590	8	0.70	0.46	0	1
Assistant Professor	1598	0	0.27	0.44	0	1
Associate Professor	1598	0	0.28	0.45	0	1
Full Professor	1598	0	0.45	0.50	0	1
Age	1574	24	48.04	10.07	28	82
Total Amnt grants 2005-07	1363	235	1868760.59	7429000.00	0	154000000
Dependent Variables						
Publications	1588	10	3.82	1.697	1	7
Teaching	1584	14	3.42	1.121	1	6
Research Assistants	1567	31	3.69	1.774	1	6
PublicationsT2	746	852	3.39	1.231	1	6
TeachingT2	746	852	3.39	1.231	1	6

Table II: Crosstabulation and means of outcomes for PIs, Co-PI, Both, and Neither, Time 1 2005-2007

	Publications		Courses		Research Assistants	
	Mean	Pearson Chi^2	Mean	Pearson Chi^2	Mean	Pearson Chi^2
Principal Investigator	3.90(.032)	69.80***	3.42(.020)	140.88***	3.59(.031)	394.65***
Co-Principal Investigator	3.52(.064)	72.77***	3.58(.049)	40.05***	3.19(.066)	91.17***
Both PI and Co-PI	4.39(.030)	479.77***	3.37(.020)	108.04***	4.26(.030)	691.59***
Neither PI nor Co-PI	3.13(.039)	461.47***	3.63(.032)	74.67***	2.80(.045)	654.68***

Mean(SE of Mean)
Weighted Data
*P<.05, **P<.01, ***<.001.

Table III: Grant Getting and Academic Work Outcomes, Time 1 2005-2007

	Publications			Teaching			Research Assistants		
	B	**SE**		**B**	**SE**		**B**	**SE**	
(Constant)	6.754	0.224		1.521	0.159		3.831	0.225	
Principal Investigator (2005-07)	0.395	0.057	***	-0.145	0.040	***	0.667	0.057	***
Co-PI (2005-07)	0.260	0.080	***	-0.002	0.057		0.153	0.081	
Both PI and Co-PI (2005-07)	0.851	0.056	***	-0.206	0.040	***	1.173	0.056	***
Female	-0.209	0.055	***	-0.143	0.039	***	0.159	0.055	**
Chemistry	0.509	0.059	***	0.173	0.042	***	1.045	0.060	***
EAS	-0.797	0.062	***	0.291	0.044	***	0.583	0.062	***
Biology	0.146	0.062	**	0.514	0.044	***	-0.186	0.063	**
Computer Science	-0.049	0.062		0.606	0.044	***	0.879	0.062	***
Electrical Engineering	0.668	0.057	***	0.197	0.041	***	0.110	0.058	
Affiliation with lab or center	0.472	0.043	***	0.002	0.030		0.572	0.043	***
Time since PhD awarded	-0.019	0.006	***	0.000	0.004		-0.047	0.006	***
Tenured	-0.229	0.106	**	0.520	0.076	***	-0.077	0.106	
Assistant Professor	-1.968	0.121	***	0.737	0.087	***	-0.888	0.122	***
Associate Professor	-1.021	0.052	***	0.622	0.037	***	-0.348	0.052	***
Age	-0.045	0.006	***	0.023	0.004	***	-0.003	0.006	
Amnt grants received 2005-07	0.000	0.000	***	0.000	0.000	***	0.000	0.000	***
R Square	0.24			0.107			0.247		
Adjusted R Square	0.238			0.105			0.245		

*P<.05, **P<.01, ***<.001
Rank: Reference category is Full Professor
Field of Science: Reference category is Physics

Table IV: Grant Getting and Academic Work Outcomes for Men and Women, Time 1 2005-2007

	Publications						Teaching						Research Assistants					
	WOMEN			MEN			WOMEN			MEN			WOMEN			MEN		
	B	SE		B	SE		B	SE		B	SE		B	SE		B	SE	
(Constant)	5.221	.442		3.767	.241		1.624	.344		1.826	.171		4.970	.490		3.767	.241	
Principal Investigator (2005-07)	-.044	.143		.675	.061	***	-.073	.111		-.145	.043	***	.565	.160	***	.675	.061	***
Co-PI (2005-07)	-.366	.186	*	.162	.087	***	.290	.145	*	-.049	.061		-.017	.208		.162	.087	
Both PI and Co-PI (2005-07)	.451	.143	**	1.210	.060	***	.100	.112		-.240	.042	***	.887	.160	***	1.210	.060	***
Chemistry	.323	.143	*	.975	.063	*	.336	.112	**	-.060	.045		.787	.160	***	.975	.063	***
EAS	-.614	.152	***	.444	.066	***	.474	.118	***	.058	.047		.816	.169	***	.444	.066	***
Biology	-.115	.139		-.248	.068	***	.539	.108	***	.296	.048	***	-.437	.154	**	-.248	.068	***
Computer Science	-.167	.176		-.113	.062	***	.606	.139	***	-.205	.044	***	.352	.196		-.113	.062	
Electrical Engineering	.809	.153	***	.815	.065	***	.020	.120		.394	.046	***	.187	.171		.815	.065	***
Affiliation with lab or center	.185	.112		.597	.045	***	-.246	.088	**	.034	.032		.439	.125	***	.597	.045	***
Time since PhD awarded	-.011	.015		-.052	.006	**	-.004	.012		.001	.004		-.022	.017		-.052	.006	***
Tenured	-.159	.195		-.272	.122	*	.355	.153	*	.538	.087	***	.516	.217	*	-.272	.122	**
Assistant Professor	1.343	.200	***	-.971	.138	***	-.301	.157		.717	.099	***	.405	.223		-.971	.138	***
Associate Professor	2.115	.253	***	-.321	.056	***	-.779	.198	***	.645	.040	***	1.066	.282	***	-.321	.056	***
Age	-.057	.013	***	.005	.006	***	.036	.010	***	.021	.004	***	-.055	.015	***	.005	.006	
Amnt grants received 2005-07	.000	.000	**	.000	.000	***	.000	.000	**	.000	.000	***	.000	.000		.000	.000	***
R Square	.269			.238			.112			.109			.230			.256		
Adjusted R Square	.257			.237			.097			.107			.217			.255		

*P<.05, **P<.01, ***<.001

Rank: Reference category is Full Professor

Field of Science: Reference category is Physics

Table V: Grant Getting and Academic Work Outcomes, Time 2 (2007-2009)

	Publications (2007-09)			Teaching (2007-09)		
	B	SE		B	SE	
(Constant)	2.015	.266		1.008	.230	
Principal Investigator (2005-07)	.214	.064	***	-.280	.059	***
Co-PI (2005-07)	.434	.085	***	-.199	.079	*
Both PI and Co-PI (2005-07)	.421	.064	***	-.284	.058	***
Female	.146	.056	**	-.159	.052	**
Chemistry	.051	.063		-.226	.059	***
EAS	-.421	.072	***	-.264	.065	***
Biology	.135	.068	*	.217	.064	**
Computer Science	-.418	.069	***	-.021	.065	
Electrical Engineering	-.171	.067	**	-.115	.062	
Formal affiliation with lab or center	.166	.047	***	.209	.043	***
Time since PhD awarded	.013	.006	**	-.033	.005	***
Tenured	.263	.114	**	-.200	.105	
Assistant Professor	.417	.133	***	.075	.122	
Associate Professor	.051	.057		.141	.052	**
Age	-.032	.006	***	.034	.006	***
Amnt grants received 2005-07	.000	.000	***	.000	.000	**
Journals T1 (2005-07)	.714	.013	***			
Teaching T1 (2005-07)				.496	.017	***
R Square	.572			.284		
Adjusted R Square	.570			.281		

*P<.05, **P<.01, ***<.001

Rank: Reference category is Full Professor

Field of Science: Reference category is Physics

Table VI: Grant Getting and Academic Work Outcomes for Men and Women, Time 2 (2007-2009)

	Publications (2007-09)						Teaching (2007-09)					
	WOMEN			MEN			WOMEN			MEN		
	B	SE		B	SE		B	SE		B	SE	
(Constant)	3.869	.552		1.590	.287		1.096	.489		1.020	.246	
Principal Investigator (2005-07)	.509	.167	**	.147	.069	*	-.467	.154	**	-.243	.063	***
Co-PI (2005-07)	.623	.226	**	.397	.092	***	.163	.210		-.232	.085	**
Both PI and Co-PI (2005-07)	.724	.164	***	.360	.069	***	-.580	.151	***	-.229	.062	***
Chemistry	-.076	.154		-.460	.076	***	-.042	.144		.010	.067	
EAS	-.669	.190	***	.115	.073		-.482	.172	**	.560	.067	***
Biology	-.292	.163		-.082	.070		-.200	.153		.253	.064	***
Computer Science	-.619	.222	**	-.503	.070	***	.290	.207		.228	.065	***
Electrical Engineering	-.019	.181		-.259	.068	***	-.092	.168		.134	.062	*
Affiliation with lab or center	.136	.126		.155	.051	**	-.112	.119		.271	.046	***
Time since PhD awarded	.011	.019		.010	.006		-.030	.017		-.032	.006	***
Tenured	-.529	.230	*	.532	.132	***	.434	.214	*	-.503	.121	***
Assistant Professor	.087	.248		.693	.152	***	-.504	.222	*	-.200	.139	
Associate Professor	.768	.309	*	.162	.061	**	-.667	.274	**	.115	.055	*
Age	-.061	.016	***	-.026	.007	***	.045	.015	**	.032	.006	***
Amnt grants received 2005-07	.000	.000		.000	.000	***	.000	.000		.000	.000	**
Journals T1 (2005-07)	.674	.038	***									
Teaching T1(2005-07)				.724	.014	***	.361	.047	***	.523	.018	***
R Square	.542			.587			.218			.315		
Adjusted R Square	.527			.584			.192			.311		

*P<.05, **P<.01, ***<.001

Rank: Reference category is Full Professor

Field of Science: Reference category is Physics

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