

WORKING PAPER

Leadership in Academic Science:

Is it What You Know, Who You Know, or Who You Are?

Marla Parker
mparke8@uic.edu

Eric Welch
ewwelch@uic.edu

Science, Technology and Environment Policy Lab
Department of Public Administration
University of Illinois at Chicago
Chicago, IL 60607

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Abstract:

This paper examines the factors associated with the attainment of leadership positions of men and women scientists. Based on the literature, we develop hypotheses for three determinants of leadership: social relationships, reputation, and gender. Social relationship recognizes the importance of the network connections; reputation recognizes the importance of science ability; characteristics include individual traits such as gender. We test the resulting model on the likelihood of attaining three different types of academic science leadership – center leadership, university administrative leadership, and discipline leadership. Regression analysis uses data from a National Science Foundation funded survey of scientists in which social network, attitudinal and behavior data were collected to understand how social networks affect career trajectories of men and women. Findings show that science reputation is strongly associated with center and discipline leadership, it is less strongly associated with administrative leadership. Also, large dense collaboration networks are important for center leadership, while the opposite is true for administrative leadership. Women are more likely to be in discipline or administration leadership positions and less likely to be a leader of a research center. Finally, having more women in the network reduces the likelihood of attaining any type of leadership position. Conclusions interpret findings for policy and management.

Leadership in Academic Science: What You Know, Who You Know, or Who You Are?

1. Introduction

We live in a culture where leadership is a mainstay in discussions about how to move organizations forward. Good leadership is frequently viewed as the panacea that can cure the ails of organizational stagnation, poor performance, instability, and unprofitability, leading to the accomplishment of organizational objectives, growth, innovation, prosperity and more. To this end, much work has been done to understand the underpinnings of leadership--especially what contributes to the creation of a leader. However, leadership determinants are still a complex area of study and remain open for more inquiry. The progressive development of science from a field with individual investigators to a highly collaborative, team based enterprise provides an interesting context for examining leadership determinants in academic science. Leadership, defined here as a formal position of authority that is officially conferred by an organization that includes the latitude to influence and direct a body of subordinates (Pfeffer, 1977), is an important topic in social studies of science because it concerns the development of human capital for the production of scientific knowledge.

This paper explores the relevance of three factors typically linked to the attainment of academic science leadership positions: social connections, scientific ability, and gender. Social connections are reflected in the relationships that academic scientists have with the people in the scientific community. Scientific ability reflects the scientific productivity and reputation of the individual. The study of gender in science leadership provides a means of examining advancement of women into important positions within the scientific community. While social connections, scientific ability, and gender have been researched individually to understand their connections to leadership, this research examines them in concert. Thus, our research question is as follows: How are social connections, scientific ability, and gender associated with attainment of leadership positions in academia? We are also interested in understanding whether the importance of three factors is consistent across different types of leadership.

The paper first conceptualizes three types of scientific leadership –center leadership, university administrative leadership and discipline leadership before building hypotheses predicting the associations between leadership and the independent variables of interest: social connections, science ability and gender. Using data from a national survey of academic scientists in six fields of science and engineering, we empirically test the hypotheses using regression analysis. Findings show that science reputation variables – grant ability, publications and awards obtained – are strongly associated with center and discipline leadership, while only grant production is associated with administrative leadership. Additionally, while many of the social relationship variables predict leadership attainment, large dense networks of strong collaborative ties are important for center leadership, the opposite is true for administrative leadership. Women are more likely to attain leadership positions in general, but this is due to the abundance of women administrative and disciplinary leaders. Females are less likely to hold a leadership position in research centers, but more likely to be administration or discipline leaders. Finally, having more

women in the collaborative network reduces the likelihood of holding any type of leadership position. Conclusions discuss implications for science administration and policy.

2. Science Leadership

Science leaders are responsible for many different types of activities designed to facilitate and enable the production of science. They attract and maintain a workforce of creative, motivated, and satisfied reputable scientists. transfer, and application of scientific knowledge within the university science setting to the external environment (Keller & Holland, 1975; Etzkowitz, 1997; Siegel et al., 2004; Gieryn, 1983; Shapin, 2008).for. They ensure that necessary equipment and resources are available and properly allocated. Science leaders are also responsible for creating and communicating organizational goals both internally and to external stakeholders (O’Leary 1999, Shapin 2008, Sapienza 2004, Etzkowitz 1997). Nevertheless, science is organized at many different levels: lab, center, department, university, and discipline. Accordingly, we conceptualize three different types of leadership positions for this study: center leadership, university administrative leadership, and discipline leadership. These leadership types are not exhaustive, nor are the mutually exclusive as it is possible to hold all three positions at once. A more in-depth discussion of these types follows.

2.1. Center Leadership

Center research leaders are individuals with formal positions (e.g. directors) at university labs and researcher centers or institutes. Among all three types of leadership, they have the most direct impact on the production of scientific knowledge. In their extensive review of studies about leadership at research and development organizations, Elkins and Keller (2003) assert that leadership in this context is critical in that its outcomes directly influence idea generation process and the quality and value of final scientific outputs. Hollingsworth and Hollingsworth (2000) provide valuable insight into the value of the visionary leadership in research labs, which they found to be integral in major discoveries and innovations. “Visionary leadership [is] the capacity for understanding direction in which scientific research is moving and integrating scientific diversity” (p. 220). The primary responsibilities of center leaders include identifying areas of research (i.e. setting research agendas), securing proper resources and capital for research, facilitating research projects, serving as a buffer between scientists and non-scientists of the academic science environment, and managing the dissemination and communication of research outputs (Shapin, 2008; Keller & Holland, 1975; Jain &Triandis, 1997; Kaplan, 1959). Most important and challenging for center research leaders is effectively fulfilling these responsibilities to meet the demands of multiple stakeholders who consume and appropriate research outputs differently while simultaneously managing the scientists who actually do the work (Elkins & Keller, 2003; Sapienza, 2004; Bland & Ruffin, 1992).

2.2. University Administrative Leadership

Administrative leaders in universities include deans, department heads and chairs, provosts and other formal administrative positions. They manage both the internal and external environments of universities in ways that facilitate the production of high quality science (Siegel et al., 2003). They are charged with developing and managing organizational policies, culture, and institutions (Del Favero, 2006), and developing incentives and reduce barriers to encourage and facilitate research and teaching. Management activities include implementation of management strategies

that respond to government initiatives and policies that influenced how universities practice and produce science (Morris 2002).

Leader actions impact the external reputation that institutions have as creative and resource rich environments that facilitate the creation of knowledge. They communicate university goals both internally and externally, and develop programs to communicate what the university and its faculty accomplish. As universities have embraced entrepreneurship of administrative leaders have sought to bridge academia and industry (Etzkowitz, 1997; Siegel et al., 2004). And, within the increasingly complex fiscal climate, administrative science leaders must secure financial resources necessary support the organization to conduct its work. Administrative leaders are responsible for compliance with laws and regulations, creating standards performance and evaluative activities that aim to continually improve the organization (Hagstrom, 1977; O'Leary, 1999; Hemphill, 1955; Hind et al., 1974; Rindova et al., 2005; Siegel et al., 2004). Essentially, administrative science leaders are predominantly involved in managing the department or university in ways that enable faculty to accomplishment of their missions (Etzkowitz, 1998).

2.3 Discipline Leadership

Disciplinary leaders include individuals who have positions in professional science associations and regulatory organizations. They focus primarily on developing and enforcing standards and norms for the scientific community as a whole, which subsequently results in impacting the culture of science. Examples include elected or appointed duties in disciplinary organizations as well as roles in such organizations such as the American Association for the Advancement of Science, the National Academy of Science, or the American Medical Association. Various responsibilities of discipline leaders include developing and administering overall professional practices such as peer review, helping to shape policies that impact science and technology development, enforcing codes of conduct, promoting insight into the benefits and limitations of science, facilitating and encouraging important policy changes in the scientific community, improving the connection between professional scientists and the public, and encouraging assessments of the scientific field (Pelligrino & Relman, 1999; Frankel, 1989; Fields et al., 2002; Eagle et al., 2003; Swan & Newell, 1995). Overall, discipline science leaders promote the professionalization and institutionalization of science (Fields et al.; 2002; Swan & Newell, 1995).

As can be implied from the discussion above, center, university administrative, and discipline leaders have similar roles in resource appropriation and managing the visibility of their organizations for the purpose of advancing the production and application of scientific knowledge. However, it can be seen that each type of leadership focuses on various aspects of those processes.

3. Science Leadership Hypotheses: Social Relationships, Science Ability and Gender

This section develops hypotheses for three general categories of science leadership – social relationships, science capacity, and gender.

3.1. Science Leadership and Social Relationships

Leadership-member exchange (LMX) theory promotes the notion that “effective leadership processes occur when leaders and followers are able to develop mature leadership relationships

(partnerships) and thus gain access to the many benefits these relationships bring” (Graen & Uhl-Bien, 1995, p.225). These benefits can be viewed as the returns from social capital in the form of information and resources that can contribute to individual success and productivity (Brass & Krackhardt, 1999; Burke et al., 2007; Hansen et al., 2001; Nahapiet & Ghoshal, 1998). Bourdieu (1985) defines social capital as “the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition” (p. 248). Coleman (1988) asserts that social capital can be conceived of as the intangible resources, information, opportunities, and control that is gained through relationships with other people and is used as a means to achieve a particular end. Lin (2002) offers that social capital concerns the resources that can be attained through social connections such as personal and social resources.

Characteristics of social networks contribute to the how information and resources are created and are thus associated with the attainment of leadership positions (Balkundi & Kilduff, 2005; Burt, 1992; Burt & Celotto, 1992). An individual’s position in the network is indicative of her power and influence (Brass & Krackhardt, 1999). Some positions enable greater control of information and resource flows, which translates into a source of influence and power for the boundary spanner (Spekman, 1979; Tushman & Scanlan, 1981; Russ et al., 1998; Aldrich & Hercker, 1977). Thus, social networks can generate information, resources, and influence (Burt, 2000).

Social structure also has visibility and reputational returns. Brass (1984, 1985) found that enhancing one’s reputation by associating with powerful groups was a key factor in these individuals being placed in management positions. Cialdini (1976, 1989) was among the first to assess this as a common phenomenon and coined this as the “basking in the reflected glory of others” phenomenon. Brass and Krackhardt (1999) further this in their study and assert that individuals “basking in the glory of prominent others” (p. 187) will be more likely to increase their own perceived reputation of power. Highly visible individuals are more likely to attain formal leadership positions, especially in public institutions (Borins, 2002).

Four characteristics of networks are expected to be associated with attainment of a leadership position: network size, network density, balance of external and internal ties, strength of ties, and. Network size refers to the number of alters in the ego’s network. A larger number of alters in an ego’s network indicates a larger potential set of individual from which the ego can obtain resources. Larger networks provide greater amounts of information and resources (Granovetter, 1973; Podolny & Baron, 1997). Attaining a leadership position requires substantial resources and support from a broad range of actors. Individuals who have higher numbers of alters in their network may be able to obtain the resources needed to attain a leadership position.

Network density reflects the number of connections among the individual within the network (Burt 1992, 2002). When network are more dense – more connections among alters, an echo chamber is created in which informational resources are highly redundant (Balkundi & Kilduff, 2005; Brass & Krackhardt, 1999). Networks that are less dense may mean that alters are connected more to others, and hence have access to greater diversity of information (Friedkin, 1982; Lin, 2002). In addition, the balance of internal versus external ties may matter for leadership attainment. Egos that have a greater ratio of external to internal ties may have access to more information and resources outside the organization (in this case the university). Individuals interested in attaining leadership positions are likely to depend up on diverse sources

of information to be able to both span boundaries to carry out their work, but also position themselves strategically in ways that increase their likelihood of attaining a leadership position.

Relationships vary in terms of their strength of ties. Strong ties imply greater emotional closeness (Lin, 2002; Granovetter, 1973) and higher levels of trust, which are likely to make people prone to sharing information and resources (Krackhardt, 1992). The more connections individuals has (i.e. larger networks), the information they have access to from various places. This also means that larger networks could provide access to more varied and less redundant information (Burt, 1992; Haythornthwaite, 1996). Because leaders are charged with marshaling a wide range and variety of resources, it is advantageous for them to maneuver between less dense networks that are larger and more externally situated. Therefore, our hypotheses related to network structure, size, and strength of ties are:

H1: Science leaders will have larger collaboration networks than non-leaders.

H2: Science leaders will have less dense networks than non-leaders.

H3: Science leaders will have a greater proportion of external network ties than non-leaders.

H4: Science leaders will have stronger network ties than non-leaders.

3.2. Science Leadership and Science Ability

Science leaders need to possess strong technical skills since they are charged with working with group members in solving research problems and advancing the development of scientific knowledge (Sapieza, 2005; Jindal-Snape & Snape, 2006; Shapin, 2008). Similarly, strong scientific ability is likely to be an important indicator of reputation, and reputation has been shown to be an important determinant of leadership attainment. The link between academic science ability and reputation is especially evident in the literature (Merton, 1957; Crane, 1965; Ben-David & Sullivan 1975; Hargens & Hagstrom, 1982; Stern, 2004). Success in science is typically measured in terms of productive outcomes and recognition. These include publishing journal articles, receiving grant awards and receiving prestigious awards that recognize scientific contributions (Sorenson & Fleming 2004; Rindova & Williamson, 2005; Arora et al., 1998; Allison et al., 1982; McMillan & Deeds, 1998; Merton, 1973; Boardman & Ponomariov 2007). This is consistent with the work of Rindova et al. (2005) who found that productive and intelligent faculty contributed to the prominence of their academic institution. Furthermore, this is consistent with findings by O'Leary (1999) who shows that science organizations typically use technical competence as primary criteria for promotion to management positions.

H5: Science leaders will have more scholarly awards than non-leaders.

H6: Science leaders will have more science outputs (grants awarded and journal articles) than non-leaders.

3.3. Science Leadership and Gender

The literature generally finds that women are less likely to connect to people with more power and authority (Agars, 2004; Ibarra 1992 and 1993; McGuire, 2000). One reason offered is that they have less access to networks in which men are in positions of authority and power. As a

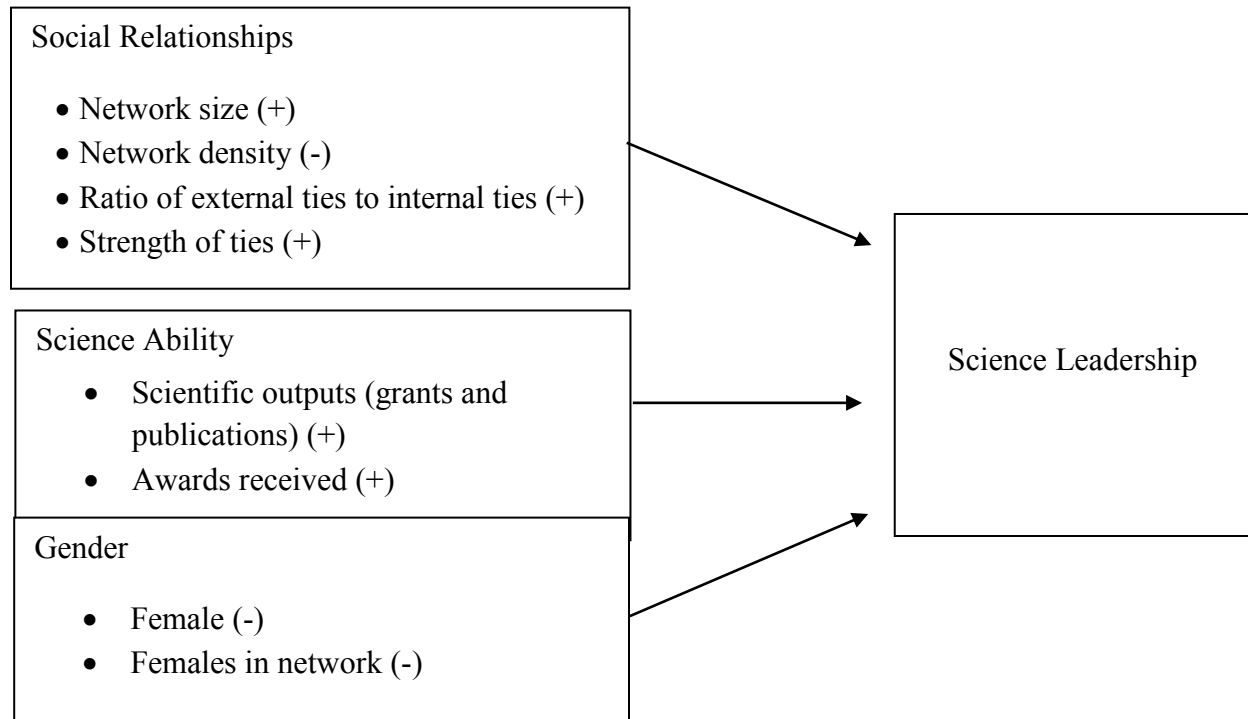
result, women may be structurally excluded from leadership positions because they lack of key social capital necessary for advancement and attainment of power (McPherson & Smith-Lovin, 2001; Ruef et al 2003). The second key difference is that women are more likely to be in rather dense, tightly knit networks (Timberlake, 2005). This is substantiated by findings that women tend to be more communal than men, meaning that they focus on fostering strong emotionally based connections (Eagly & Johannesen-Schmidt, 2001). Women as compared to men have fewer weak ties which means that they are less able to make connections across different types of networks that are located within and outside of the organization (Burt, 2000). In general, the literature shows that being a woman in science is likely to reduce the likelihood of attainment of a leadership positions.

H7: Women will be less likely to be science leaders than men.

H8: Science leaders will have fewer women in their networks than non-leaders.

When considering the previous discussion it is now possible to develop a conceptual model (Figure 1 below) to map how we conceive of the relationship between gender, social networks, as well as technical expertise and academic science leadership.

Figure 1: Conceptual Model for Individual Associates of Academic Leadership



4. Data and Methods

Data for this study is from a 2007 National Science Foundation funded survey administered by the University of Illinois at Chicago, the Georgia Institute of Technology, and the University of Georgia. This was a national survey conducted among scientists and engineers at 150 Carnegie-designated Research I (or Research Extensive) universities. Several data points were collected:

individual background, career timeframe and experiences, research and teaching responsibilities, productivity, and social networks. The survey is unique in that it collects detailed information about the aspects of individual's sub-networks and not the global network (Wasserman & Faust, 1995). Detailed survey questions inquiring about the individual's activities and relationships within these network capture dimensions of the collaborative and advice networks that are not accessible through existing data such as bibliometrics. The value of this is that more insight can be gained into how specific networks and the relationships fostered within them are important for career outcomes and the production of scientific outputs (Burt & Minor 1983; Straits, 2000; Marin, 2004).

Network data was collected using a series of name generator and name interpreter questions. First, respondents were given five name generator questions asking them to provide the names of key collaborators or advisors in research collaboration as well as advice and support networks. These included closest collaborators within their own university, closest collaborators outside their university, individuals with whom "they talk about their research but have never collaborated. In addition, they were asked provide the names of individuals who provided them advice in two contexts— those with whom they talk about career advice and with whom they discuss departmental matters. It is important to note that while the research and advice networks are mutually exclusive, there is some overlap. Once the survey respondent provided names in each of the five name generator questions, the names were piped into a series of name interpreter questions focusing on the respondent's activities with the individuals named and the nature of the relationship between the two. More specifically, these name interpreter questions inquired about the type of the collaboration undertaken with the collaborator, details about the level of relationship and how they met, closeness of research expertise, communication frequency, grant activity, and general demographics. Data collected through the name interpreter questions (i.e. alter-level data) were aggregated into sums and averages that were further aggregated into network variables for each respondent. This provided summary data about each of the respondent's networks. In addition to the name generator and interpreter questions, respondents were asked about their research activities, including grant submission and success rate, teaching and committee responsibilities, attitudes about and involvement in interdisciplinary research, work environment, and detailed demographic and academic background questions.

A random sample of 3,667 participants stratified by sex, rank, and discipline was developed from the population of academic scientists and engineers in six scientific disciplines (biological sciences, chemistry, computer science, earth and atmospheric sciences, electrical engineering, and physics) in the Research I universities. The disciplines were selected based on the level of female representation in those fields (low, transitioning, and high fields). The population was constructed using a two step process. First, web pages of departments that best reflected the disciplines of interest and directories were found online. Second, information (i.e. name, gender, and individual websites) for faculty that could be clearly identified as assistant, associate, or full professors was copied into a population database. Sample weights were calculated using the inverse of the probability of selection and employed in calculating results for this study.

A total of 1,774 completed surveys were received. Of those, 176 were removed due to ineligible rank or discipline. There were 21 surveys where the respondents had responded to over 95% of the questions, and thus they were included as well. The resulting final sample size used for analysis was 1,598. 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 43.0% (AAPOR 2009).

This was an online survey developed using Sawtooth Software®, which provided the necessary capacity to handle the complex nature of name generator and name interpreter questions. Postal and electronic mail invitations were distributed to individuals inviting them to participate in the survey. Both types of invitations provided a personalized username and password that allowed respondents to securely access the survey. Reminder emails were also sent to increase response rates. Overall, the survey took between 30 and 45 minutes to complete.

4.1 Measures

Dependent variables:

Four main dependent variables capture leadership in this paper. Three operationalize each of the three types of leadership – center, administrative, discipline – while a fourth combines all three into a single indicator of science leadership. A Center Leader is a faculty member that holds a current position as a director or co-director of a primary lab or a director of a research center or institute. To capture this variable we used responses to two questions. The first question asked respondents to indicate if they were a director or co-director of a permanent science or engineering laboratory or center (1=yes). The second question asked respondents to indicate whether they currently hold a position as a director of a research center or institute (1=yes). Because these questions may capture the same position, we transformed this variable to a discrete one-zero indicator of center leadership (1=yes).

A University Administrative Leader is operationalized as an individual responded that they either currently hold a position as dean or they hold a position as department head or chair. This was transformed into a discrete one-zero indicator of administrative leadership (1=yes). Discipline Leaders include all faculty respondents that indicated they currently hold a position as an officer in a professional association. In the survey, individuals first named the set of associations in which they were members. A subsequent question piped the association names into a name interpreter questions that asked respondents to indicate whether were currently an office holder. In some cases, scientists held offices in more than one association. For the purposes of this study, we transformed this variable into a discrete one-zero indicator of discipline leadership (1=yes). In addition, we combined the three leadership variables into a discrete one-zero indicator of Science Leader (1=yes).

Independent variables:

The independent variables of interest are the respondent's science ability, aspects of their social relationships, and gender. Science ability reflects an individual's ability to produce scientific knowledge. Production of science publications and grants are a common way to assess scientific ability. Several questions on the survey captured this. One open-ended question asked respondents to estimate the average number of publications they had submitted in the last five academic years. Another open-ended question asked respondents to indicate the average number of research grants submitted in the last five academic years. Lastly, respondents were asked if they had been the recipient of any of the following awards: dissertation or "best paper, a National Science Foundation career grant, a National Science Foundation fellowship, a young investigator award, or another science or engineering award (1=yes). The total number of awards was calculated. All three variables measuring science ability are continuous.

For the purpose of this study, social relationships were assessed using the respondent's collaboration network – the network of individuals both inside and outside of the respondent's institution with whom they collaborated on research with. Two name generator questions in the survey capture this: “over the past two academic years, which individuals at your university have been your closest research collaborators” and “over the past two academic years, who have been your closest research collaborators outside of your institution (including other academic institutions, government and industry”. Respondents were limited to naming five individuals for each name generator such that respondents were limited to a total of ten possible close collaborators.

As mentioned previously, network structure, network size, the strength of ties in the network, and the number of women in the network are the variables of interest. The structure of the collaboration network is measured two ways: density and the E-I index. Network density reflects the extent to which alters in the respondent's network are connected to each other and is measured by dividing the total number of ties in the collaboration network by the total number of possible ties. The E-I index assesses the extent to which a respondent's network is situated more or less externally to his or her university. Krackhardt and Stern (1988) developed an E-I index to capture the relationship between external and internal links of an individual's network. For this study, external links are specifically the collaborative ties between the respondent and named close collaborators outside the respondent's university; internal links are collaborative ties between the respondent and named collaborators inside the respondent's university. The specific calculation for the E-I index is as follows:

$$\text{E-I index} = (\text{ECL} - \text{ICL}) / (\text{ECL} + \text{ICL}),$$

where ECL is the number of external collaborative links and ICL is the number of internal collaborative links. Scores the E-I index range between -1.0 and +1.0. As the E-I index approaches +1.0, the ratio of external links to internal links increases. As the E-I index approaches -1.0, the ratio of internal links to external links rises.

In addition, we measure the total size of the collaboration network as the sum of the collaborators named by the respondent. The strength of ties is measured by the average number close friends in the respondent's collaboration network (1=yes). This was captured by a name interpreter question in the survey where the respondent to “please indicate if this person is a close friend”.

To measure the women in the respondent's network, we summed the number of collaborators who are female. The gender of the respondent is measured as a dichotomous variable (1=female). Control variables include scientific field (biological sciences, chemistry, computer science, earth and atmospheric sciences, electrical engineering, and physics), age, and age squared. A summary of the dependent, independent, and control variables is in Appendix A at the end of this paper.

4.2 Methods and Model

Because the dependent leadership variables are measured using discrete one-zero indicators logistic regression analysis was used to predict the likelihood of leadership. Sample weights were

used and listwise deletion of observations due to missing values resulted in a sample size of 1,317 used in the estimations.

Four regression estimations were developed and estimated using the logistic regression analysis. Three were used to predict the likelihood of discipline leadership, administrative leadership, and center leadership. The fourth model was used to predict the likelihood of total science leadership and was used to accept or reject the presented hypotheses. The final empirical model can be expressed as:

$$\text{Science Leadership} = f[\text{Science Ability (grants submitted, publications submitted, awards earned), Social Relationships (collaboration network size, density, EI Index, close friends, number of women in collaboration network), Female, Controls (minority, field, age, age squared)}]$$

4.3 Descriptive Statistics

Descriptive tables are provided below. Table 1 provides descriptives for the dependent and independent variables. Table 2 presents ANOVA results for differences of means between men and women for the different types of leadership.

Table 1. Descriptive Statistics

Variable	N	Mean	Standard Deviation
Dependent Variables			
Total Science Leadership	1598	0.26	0.44
Center Leadership	1598	0.07	0.26
Administrative Leadership	1598	0.05	0.21
Discipline Leadership	1598	0.18	0.39
Independent Variables			
Science Capacity			
Average Grants Submitted	1554	2.55	2.39
Average Publications Submitted	1589	3.76	5.36
Total Awards Received	1598	0.67	0.79
Social Relationships			
Density of Network	1394	0.47	0.24
E-I Index	1436	0.00	0.53
Average number of close friends in network	1435	0.23	0.28
Total Size of Network	1436	5.09	2.45
Total Number of Females in Network	1435	0.73	1.06
Gender			
Female	1598	0.46	0.50
Controls			
Minority	1598	0.04	0.21
Chemistry	1598	0.18	0.38
Computer Science	1598	0.16	0.37

Electrical Engineering	1598	0.13	0.34
Biological Sciences	1598	0.17	0.38
Physics	1598	0.17	0.38
Age	1574	48.04	10.07
Age-squared	1574	2408.89	1010.57

Among the dependent variables, it can be seen that slightly more than a fourth of all respondents are science leaders (0.26); are discipline leaders (0.18), followed by center leaders (0.07), and administrative leaders (a mean of 0.05). Distribution of leadership types by gender in Table 2 shows that women are more likely to report being a leader (male 0.23; female 0.27), while men are generally more likely to be leaders for the types of leadership position. This indicates that men are more likely to have multiple leadership positions than women.

Table 2. Difference of Means, Male and Female Leadership

Leadership Type	Male		Female		Significance
	N	Mean (SD)	N	Mean (SD)	
Discipline Leadership	867	0.13(.34)	731	0.21(.411)	***
Administrative Leadership	867	.05(.22)	731	.03(.18)	***
Research Leadership	867	.09(.29)	731	.05(.22)	*
Total Science Leadership	867	.23(.42)	731	.27(.44)	***

Significance: $p < .10^*$, $p < .05^{**}$, $p < .01^{***}$

Among the independent variables, the average number of grants submitted being 2.55, average publications submitted being 3.76, and the average awards earned being 0.67. But when considering that the average age of the respondents is 48 years old and approximately half of the respondents are women (mean of 0.46), the relatively low science capacity is not surprising. Women scientists and engineers typically produce less and overall, most academic scientists do not start to produce a significant amount of outputs (especially grants) and receive recognition for their work until in their 40's.

Respondents report an average of five collaborators (network size) and fewer than one in five is female. This statistic represents the approximate percentage in the combined populations of the six different fields. Approximately 23 percent of all collaborators named in the survey are close friends (strong ties) of the respondent and 47 percent of all ties named know each other (density). An E-I Index of zero indicates that on average scientists have report as many internal as external ties.

5. Estimation Findings

Tables 3 and 4 present the results from the model estimations from the regression analysis. Table 3 provides results for the total science leadership and discipline leadership models. Table 4 provides results for the center and administrative leadership models. All models also provide odds ratios for each independent variable, which generally indicates how important each variable is in predicting science leadership. As mentioned previously, the model estimating total science leadership (see Table 3) will be used to determine whether or not the hypotheses can be accepted.

First, we can examine the estimation results for the total science leadership model (Model 1). All of the measures for science ability are significant at the $p < .01$ level and are positively related to total science leadership. This means that more awards and submitted grants and publications contribute to the attainment of leadership positions. These findings support our hypotheses H5 and H6 that science ability is associated with leadership attainment. Additionally, all of the social relationship measures related to collaboration networks are significant at the $p < .01$ level, except for density which is significant at the $p < .05$ level. Also, all of these measures except for the network density, number of women in the network and the E-I index are positively related to total science leadership as well. This means that larger, less dense collaboration networks with strong ties (i.e. having more close friends) contribute to the attainment of science leadership positions. These findings support our expectations as presented in H1, H2 and H4. It is possible that dense networks are more important for some kinds of leadership than for others. Additional analysis of different types of leadership will provide further clarity for this finding.

The number of women in the collaboration network and the ratio of external to internal ties in the collaboration network are significantly, but negatively related to the attainment of science leadership positions. In other words, having fewer women in one's collaboration network and having fewer external ties in one's collaboration network is more likely to lead to the attainment of science leadership positions. The findings tend to support our expectations regarding females in networks (H8), but are again opposite of the expectations stated in H3 that external ties would be more important for leadership. An increase of one woman in the network reduces the likelihood of being a leader by 0.87. Further analysis below will explore this. Finally, we find that female is positively and significantly related to the attainment of science leadership positions; being a woman increases the likelihood that one will attain a science leadership position. Odds ratios show that being a woman increases the likelihood of being a leader by a factor of 1.59. Further analysis on disaggregated leadership dependent variables will help provide some clarity about this.

Results from the discipline leadership (Model 2) are similar to the overall model (Model 1). However, center and university administration leadership models (Models 3 and 4 respectively) diverge. Although, we find the same results for science ability for center leadership as we did in Models 1 and 2, we also see that density is positively associated with center leadership while being female is now negatively associated with center leadership. It seems that more connected networks of alters may be important for center leadership in which individuals are collaborating intensely on projects. However, this context does not benefit women, who may be excluded from leading these types of localized, dense collaborative networks.

Table 3. Estimation Results: Total Science Leadership and Discipline Leadership

	Model 1: Total Science Leadership				Model 2 : Discipline Leadership			
	Coefficient	Standard Error	Significance	Odds Ratio	Coefficient	Standard Error	Significance	Odds Ratio
Science Ability								
Average Grants Submitted	0.05	0.01	***	1.05	0.03	0.01	**	1.03
Average Publications Submitted	0.04	0.00	***	1.04	0.02	0.00	***	1.02
Total Awards Given	0.23	0.04	***	1.25	0.31	0.04	***	1.36
Social Relationship								
Density of Network	-0.39	0.13	**	0.68	-0.44	0.17	**	0.64
Ratio of External to Internal Ties	-0.38	0.06	***	0.68	-0.02	0.08		0.98
Average Number of Close Friends	0.54	0.10	***	1.71	0.67	0.11	***	1.96
Size of Collaboration Network	0.14	0.01	***	1.15	0.17	0.02	***	1.18
Total Females in Collaboration Network	-0.14	0.03	***	0.87	-0.07	0.04	**	0.93
Female	0.46	0.08	***	1.59	0.72	0.09	***	2.06
Control Variables								
Minority	0.46	0.14	***	1.59	0.65	0.14	***	1.91
Chemistry	-0.56	0.11	***	0.57	-0.58	0.12	***	0.56
Computer Science	-0.44	0.11	***	0.65	-0.54	0.12	***	0.58
Electrical Engineering	0.19	0.10	*	1.21	0.12	0.12		1.13
Biology	-0.30	0.09	***	0.74	-0.38	0.10	***	0.69
Physics	-0.26	0.10	***	0.77	-0.30	0.11	***	0.74
Age	0.41	0.03	***	1.51	0.25	0.03	***	1.28
Age-Squared	0.00	0.00	***	1.00	0.00	0.00	***	1.00
Intercept	-13.56	0.79	***	1.00	-9.69	0.85	***	
Model Summary								
n	1317				1317			
Likelihood Ratio	875.60				583.98			
Prob > Chi-Squared	***				***			

Significance: p<.10*, p<.05**, p<.01***; Reference category for science field is Earth and Atmospheric Sciences

Table 4. Estimation Results: Center Leadership and Administrative Leadership

	Model 3: Center Leadership				Model 4 : Administrative Leadership			
	Coefficient	Standard Error	Significance	Odds Ratio	Coefficient	Standard Error	Significance	Odds Ratio
Science Ability								
Average Grants Submitted	0.12	0.02	***	1.13	0.09	0.02	***	1.10
Average Publications Submitted	0.02	0.00	***	1.03	0.01	0.01		1.01
Total Awards Given	0.24	0.06	***	1.27	0.01	0.08		1.01
Social Relationship								
Density of Network	0.39	0.22	*	1.48	-0.62	0.24	**	0.54
Ratio of External to Internal Ties	-0.68	0.11	***	0.51	-0.26	0.11	**	0.77
Average Number of Close Friends	0.59	0.15	***	1.80	-0.39	0.20	**	0.67
Size of Collaboration Network	0.19	0.02	***	1.20	-0.05	0.02	**	0.95
Total Females in Collaboration Network	-0.16	0.05	***	0.85	0.02	0.06		1.02
Female	-0.27	0.15	*	0.77	-0.37	0.18	**	0.69
Control Variables								
Minority	-0.02	0.23		0.98	0.24	0.24		1.27
Chemistry	-0.37	0.20	*	0.69	-0.37	0.17	**	0.69
Computer Science	0.31	0.17	*	1.37	-0.54	0.18	***	0.58
Electrical Engineering	0.61	0.17	***	1.84	0.03	0.17		1.03
Biology	0.65	0.15	***	1.92	-0.91	0.18	***	0.40
Physics	0.19	0.16		1.21	-0.98	0.19	***	0.38
Age	0.34	0.05	***	1.41	1.05	0.10	***	2.86
Age-Squared	0.00	0.00	***	1.00	-0.01	0.00	***	0.99
Intercept	-15.15	1.35	***		-30.11	2.52	***	
Model Summary								
N	1317				1317			
Likelihood Ratio	589.10				363.96			
Prob > Chi-Squared	***				***			

Significance: p<.10*, p<.05**, p<.01***; Reference category for science field is Earth and Atmospheric Sciences

Administrative leadership is not predicted by awards or journal publications; however it appears that grant getting ability may demonstrate an important type of resource building skill that is valued at the university. It should be noted here that the reverse may also be true: administrative leadership would tend to reduce ability of scientists to produce. Additionally, similar to center leadership, women are less likely to be university administration leaders. The ratio of external to internal ties is again negative. Findings show a return to a negative sign on the significant density but a reversal of sign for tie strength and network size. This may indicate that deans, department heads and chairs are less likely to engage in research or maintain strong collaborative ties.

Finally, in terms of the control variables we see that minorities, like females, are more likely to hold discipline leadership positions. There are disciplinary distinctions related to leadership type, however all models tend to show that older people are more likely to be leaders but that there are non-linear limits to the relationship as age squared is negative in all models.

6. Discussion and Conclusion

This study sought to understand how science ability, social relationships, and gender are associated with science leadership. We find that leadership is associated with all three, but at different ways depending upon the type of leadership position. Science production is generally associated with holding a science leadership position. Although, university science leaders are less likely to have large, dense collaborative networks as their administrative roles probably limit their ability to conduct research. Center leaders continue to seek grant funding and produce papers, as do discipline leaders.

Findings on network structure indicate that individuals who take on different leadership positions also depend upon very different sources of resources and information. Center leaders have smaller, denser networks and stronger ties: factors important for a high trust collaborative research environment. Discipline leaders continue to exhibit large networks of strong ties, but the ties are less likely to know each other than individuals who are not discipline leaders. This makes sense for discipline leaders: they have a high degree of network betweenness, situated between trusted collaborators who do not know each other. This enables them to obtain and control the flow of resources, and enhance their influence. Administrative leaders have networks that are less dense, smaller, more internal and made up of a smaller proportion of close friends, than those of non-administrative leaders. Perhaps if we captured a different type of network, other than collaboration networks, we would see different structural patterns. Nevertheless, it is interesting to note that although administrative leaders guide universities, they are somewhat isolated from the research community they are supposed to lead.

Female is significantly associated with the likelihood of having science leadership positions in general, but this is primarily because of the higher likelihood that women are in positions discipline leadership positions. Women are less likely to be center or university leaders: positions that are more likely to control resources and more likely to have direct effects on the conduct of science. There at least two reasons why women are more likely to be discipline leaders: women are more willing to provide service to the discipline and there are fewer women available and a higher demand for female representation in professional associations (Twale & Shannon, 1996; Chamberlain, 1988). Having more women in one's collaboration network decreases the likelihood of having a science leadership position. While this seems paradoxical on the surface, it is consistent with literature indicating that while women are assets as leaders,

their presence in social networks can be detrimental because they cannot generate as much social capital for those possibly wanting a leadership position (Carless, 1998; Day, 2001; Ibarra 1993; Vecchio, 2002; Smith-Doerr, 2004) .

There are limitations to this study that could shed more light on leadership in science organizations. First, we were limited to survey data that measured formal leadership positions currently held among faculty. Hence, we know little to nothing about faculty members' informal leadership positions or activities. Furthermore, the study is limited by the cross sectional nature of the data. A longitudinal analysis would be able to examine how networks and productivity change over time as a result of being a leader. Nonetheless, the current study does have implications for research in that it underscores the very complex nature of leadership and that even in one context, multiple dimensions are present that deserve careful attention.

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Appendix A: Variables and Measures

Factors	Variables	Related Survey Questions/Transformed Variables	Measurement
Leadership	Discipline Leadership	Please list the academic and professional associations in which you are most active. (Association name generator question) For the associations that you named, please indicate if (you are a current office holder).	1=yes
	Center Leadership	Please indicate your affiliation with this laboratory: (Director or Co-Director, Researcher); and Do you currently hold any of these positions: (Director of a Research Center or Institute)	1=yes
	Administrative Leadership	Please tell us whether you currently hold, or have ever held, any of these positions: (Department Chair/Head or Dean)	1= yes
	Total Science Leadership	All three above questions	1=Leader
Science Ability	Submitted Grants	Over the past five academic years, on average how many peer-reviewed journal articles have you published per year?	Number
	Submitted Publications	Over the past five academic years, on average how many peer-reviewed journal articles have you published per year?	Number
	Awards Received	Have you ever received a dissertation or "best-paper" award?; NSF Career Grant; NSF Fellowship; Young Investigator award; Other science or engineering fellowship or award?	Sum of awards.
Social Relationships	Network Density	Over the past two academic years, which individuals at your university have been your closest research collaborators	Density equation in methods section.
	E-I Index	Over the past two academic years, who have been your closest research collaborators outside of your institution?	EI Index equation in methods section
	Network Size	Over the past two academic years, which individuals at your university have been your closest research collaborators? Over the past two academic years, who have been your closest research collaborators outside of your institution?	Sum of all people named.
	Strength of Ties	Please indicate if this person is: (in government, female, a close friend, senior to you, junior to you, neither senior nor junior to you)	Averaged number of „close friend“ selected
	Number of Females in Network	Please indicate if this person is: (female)	Sum of females

Appendix A: Variables and Measures (continued)

Gender	Female	Are you? (female, male)	1=Yes
Controls	Minority	What is your race/ethnicity? (Blacks/African American, Latino/Hispanic, and Native American)	1=Yes
	Science Field	What is your discipline? (biology, chemistry, physics, earth and atmospheric sciences, electrical engineering, and computer science)	Six Dummy Variables
	Age	What is the year of your of birth?	2007 minus response
	Age squared	What is the year of your of birth?	Age squared