Determinants of Multifaceted Collaborative Relationships in Science and Engineering Fields

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Abstract: This paper addresses the question: What human and social capital factors determine multifaceted collaborative relationships among scientists in six fields of science and engineering? Borrowing literature from social network and S&T human capital, this paper develops a multi level model of multifaceted collaborative relationships and presents a set of testable hypotheses. Then using data from a national survey of men and women faculty in six fields, we analyze the multi level data: relationship/tie and ego level with hierarchical linear modeling (HLM) technique to predict multifaceted collaborative relationship. HLM findings indicate that relational factors of social network are positively associated with multifaceted relationship. When the ego and alter are both female faculty, the collaborative relationship is less likely to multifaceted. Findings also indicate that S&T human capital factors such as affiliation to labs, and interdisciplinary publications are positively associated with multifaceted collaborative relationships. We conclude by discussing the implications of these findings for research and science policy.

Introduction:

This paper is concerned with "multifaceted collaborative relationships" where multifaceted collaborative relationship is defined as a collaborative relationship in which ego and alter collaborate with each other in multiple contexts or facets of collaborative activities such as collaboration on grant proposal, conference paper, journal article, product development, and patent application. The setting for this research is collaboration among academic scientists. The goal of this paper is to improve our ability to predict multifaceted collaborative relationship among academic scientists in science and engineering fields. To do so, we propose a model of multifaceted collaborative relationship by linking relational characteristics of social network (strength and length of the relationship), homophily, and scientific and technical human capital.

We build a model that predicts the likelihood of multifaceted collaborative relationships by integrating the concepts of generative capacity and embeddedness. McEvily and colleagues (2003) discuss the capacity of increasing the scope of the existing relationship by incorporating additional facets to it use the term generative capacity. This capacity of the relationship to generate additional facets is based on personal interactions over a period. Similarly, Uzzi (1996, 1997) used the concept of embeddedness to describe close and personal relationships that involve fine-grained information transfer. Uzzi defines fine-grained information transfer as frequent and tacit information transfer between two parties in a relationship. As ego and alter in a strong relationship interact over a period of time, an exchange of fine grained or tacit information takes place between them which exposes them to additional facets or contexts that are outside the narrow concerns of the existing context leading the relationship to be multifaceted.

While, a number of studies have discussed multiplex relationships, few studies talk about multifaceted relationships and how multifaceted relationships are different from multiplex relationships. Multiplexity means when a tie itself becomes thicker because there are additional layers, dimensions, or relational contents. Formally, multiplexity is the number of

relations within a given link (Galaskiewicz and Wasserman, 1993). Instead of just involving exchange on collaboration, a relationship might also involve resource exchange, advice, friendship. However, our study is concerned with multifaceted collaborative relationships. For example, based on positive experience developed in one facet or encounter of the collaborative relationship, the two parties may decide to extend their collaboration to a new collaborative activity. More specifically, multifaceted collaborative relationship is a collaborative relationship in which ego and alter collaborate with each other in multiple collaborative activities.

This study tries to link three sub areas of relational characteristics of social network —1) ties based on types of resources exchanges: instrumental ties and expressive ties, 2) composition of the tie (homophilous tie), 3) relational characteristic of tie (strength of ties). It may be possible that the association between homophily, and other properties of network tie is dependent human capital endowments such as lab affiliation, and interdisciplinary publication. Integration of these three sub areas of social network is expected to result in a more robust and comprehensive model of multifaceted collaborative relationships. In an academic context, there have been few studies that systematically integrate the three sub areas of social networks. Our study provides a platform to link –homophily of ties, strength of ties, and instrumental ties to predict multifaceted collaborative relationships among scientists.

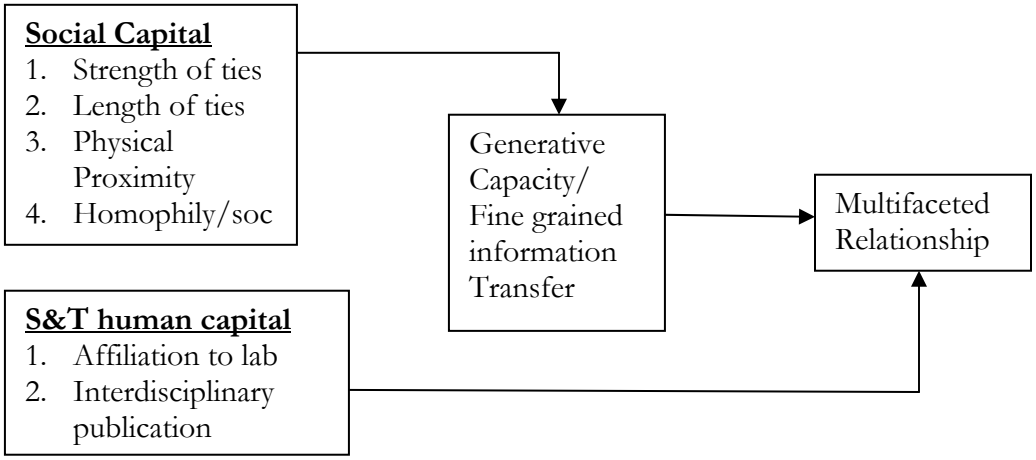
Also, there is a well developed theoretical literature that discusses that stronger ties/relationships over a period of time expose both parties in a relationship to facets beyond the narrow concerns of the existing context/facet leading to multifaceted relationships (Lewicki et al, 1998; Uzzi, 1996, 1997, McEvily et al 2003). There is a need to test this theoretical perspective in an academic setting.

The data for the paper is from a NSF sponsored online survey of academic scientists in six fields of science and engineering. The survey provides an opportunity to explore data at both relationship level and ego level. Method used in the paper is Hierarchical Linear Modeling. HLM is used to estimate two level hierarchical linear model, relationship/tie level (level 1), and respondent/ego level (level 2).

The paper is divided into four sections. The next section provides a detailed conceptualization of multifaceted relationships and how they are different from multiplex relationships. A review of relevant literature and the development of hypotheses and the theoretical model of multifaceted collaborative relationship follow this. The fifth section presents the, the empirical model, measures, and method. Finally, we present HLM findings.

Literature Review and Hypotheses:

Fig 1: Conceptual Model of Multifaceted relationships



Social and human capital determinants of multifaceted collaborative relationships:

What relational characteristics of network ties influence multifaceted collaboration among scientists? Few studies have focused on this issue in an academic context, though there are more general results that hold bearing on the question. For instance, research on homophily indicates that people have ties with those who are similar to them based on socially important attributes such as race, gender, age etc(Ibarra, 1992, 1995, 1997; Brass, 1995, 1998). We also have evidence that physical proximity increases the likelihood of interaction between pair of actors (Zahn, 1991). Multifaceted collaborative relationship between ego and alter depends on characteristics of the relationship such as strength, length, and closeness of the relationship. Specifically we propose that multifaceted collaborative relationship is a function of "closeness" of the relationship. We include strength and length of relationships and friendships under the umbrella of close relationships.

Strength of ties refers to relationships that are characterized by frequent close and personal interactions (Granovetter, 1973). Strong relationships are more likely to exchange information of greater depth and richness. Exchange of information of greater depth and richness expose both ego and alter to each other's area of expertise. In addition, the information exchange in a strong relationship may also expose both ego and alter to another activity beyond the current one leading to relationship from unifaceted to multifaceted. Relationship is multifaceted when it involves interaction in different contexts, or facets, for instance in a collaborative relationship, ego and alter may collaborate on a grant proposal, on a conference paper, on a journal article, on product development, and on a patent application. In other words, a multifaceted collaborative relationship involves the interaction of the ego and alters on a number of collaborative activities.

The longer the time period over which ego and alter know each other, the relationships tends to be more mature with greater specification and detail. The effects of greater specification and detail create conditions for multifaceted relationships. Relationships

become mature with interaction frequency, duration, and diversity of challenges that both ego and alter face together. Interaction over a longer period exposes both ego and alters to get engaged in activities beyond their current causing the relationship to be multifaceted (Lewicki et al, 1998). In the process of interaction over a period, a fine-grained information transfer is set in place that provides a platform for both ego and alters to explore contexts beyond the narrow concerns of the existing activity of the relationship (Uzzi, 1996, 1997).

The network literature discusses expressive network relationships as those relationships that are characterized by higher levels of closeness. A friendship is a expressive relationship that not only provides psycho social support but also perform functions related to work (Lincoln and Miller, 1979). As friendships are characterized by greater levels of closeness, there is a probability that both ego and alter may be involved in a number of collaborative activities. Strength, length, and expressive relationships are indicators of closeness of the relationship. Therefore, we hypothesize:

H1: Closeness will be positively associated with multifaceted collaborative relationship

We have consistent evidence that physical proximity increases the likelihood of communication between a pair of actors by increasing the probability of interactions (Zahn 1991, Monge et al. 1985). With increased interaction, a fine-grained information transfer provides a platform for both ego and alters to collaborate and further explore new collaborative activities beyond the current one (Uzzi, 1996, 1997). In other words, scientists may have a higher likelihood of forming multifaceted collaborative relationships with scientists who are in their own institutions compared to scientists that are outside of the institutions. Specifically, scientist may collaborate with fellow scientists in their own institution on a number of collaborative activities. Therefore: we hypothesize,

H2: Physical proximity will be positively associated with multifaceted collaborative relationship

The nature and scope of opportunities available through a personal network are dependent on the types of people one interacts with. More specifically, the ease of formation of a relationship depends upon the characteristics of the contact (Ibarra, 1993). Social proximity or homophily refers to the degree to which pairs of individuals who interact are similar in identity, demographics, rank, race, ethnicity, and gender. Prior research on homophily suggests that interpersonal similarity increases ease of communication, improves predictability of behavior, and fosters reciprocal relationships. Homophily is the characteristic of the tie in this paper. People working in the same department or people who have similar ranks tend to share similar ways of looking at problems and this common way of looking at problems facilitates interaction and further strengthens the relationship (Alderfer, 1987). Therefore, we hypothesize:

H3: Homophily of rank will be positively associated with multifaceted collaborative relationship.

Social network literature discusses two types of ties based on the type of resource exchanged: instrumental ties and affective or expressive ties. Instrumental ties arise in the

course of work role performance and involve exchange of hard social capital such as information, expertise, and professional advice (Ibarra, 1993; Van Emmerick, 2006). This paper is primarily concerned with instrumental ties, specifically collaborative ties among scientists. Lin (1981, 1999) argues that individuals in the work place may prefer to interact with higher status others to gain access to instrumental resources. Ibarra (1992) found that men had a greater average number of multiplex ties with men than women have with women. Prior research in science and technology field has discussed the barriers that women face in science and engineering fields, from factors such as discrimination, to work family imbalances, to ineffective mentoring (Rosser, 1999, 2002, Tobias, 1992; Fox, 1984, 1985, 1992; among others). In an academic setting, women have smaller networks than men across their career (Bozeman and Corley, 2004). Since women are structurally in a disadvantaged position, they are more likely to interact with men to gain access to instrumental resources.

In addition, literature suggests that women attempt a division of labor, obtaining social support and affective resources from women and relying on men for gaining access to instrumental resources. Why do women differentiate their choice of accessing different kinds of resources? Ridgeway et al, (1999) suggest that women rely on men for instrumental resources because of the societal expectation of gender appropriateness that emphasize men to endorse instrumental, hard social capital, and women to endorse expressive, soft social capital. Seeking instrumental resource from men is an adaptive strategy (Ibarra, 1992). While this strategy is adaptive, it has some hidden consequences for women. An important consequence of this adaptive strategy of differentiating their choices, plausibly to gain access to expressive resources from women, and instrumental resources from men is the abundance of weak ties. Weak ties may not be multifaceted. This study is concerned about multifaceted collaborative relationship, number of collaborative activities in a relationship. A relationship is multifaceted when ego and alter collaborate on more than one collaborative activity. Therefore:

H4: Homophily of gender will be negatively associated with multifaceted collaborated relationships

S&T human capital and multifaceted relationships

Scientific and technical human capital is defined as human capital endowment as well as social network ties (Bozeman et al, 2001). However, there appears to be few attempts to integrate the human capital endowments and relational characteristics of social network (strength and length of relationship) and attributes/composition of the network tie (homophily to study collaborative relationships. This study attempts to integrate human capital and relational attributes of social capital to study multifaceted collaborative relationships. Prior research in science and technology field has shown the importance of social and human capital factors in shaping collaborative strategy of researchers. For instance, Bozeman and Corley (2004) investigated the role of human capital and social capital variables in predicting a mentor strategy. This study focuses on the role of specific relational attributes of network ties, such as strength of tie, length of relationship, homophily of gender and rank within a network tie as well human capital endowments such as affiliation with a lab and interdisciplinary publications (controlling for disciplines, rank, and productivity) have on multifaceted collaborative relationships. Numerous human capital variables may contribute to multifaceted collaborative relationships. Affiliation to federal

labs may provide access to new sets of collaborative networks and relationships. It may be reasonable that access to larger collaborative networks may provide access to equipments and other facilities. Meadows and O'Connor (1971) suggest that joint access to equipments is a motive for forming collaborative relationships. Joint access to equipments may provide opportunities to collaborate with other scientists on a large number of collaborative activities. Therefore, we hypothesize,

H5: Affiliation to a lab will be positively associated with multifaceted collaborative relationship

Rhoten (2007) argues that scientists who are attracted to interdisciplinary work prefer team based collaborative approaches. It may seem reasonable that scientists who have a higher percentage of interdisciplinary work more diverse experience. In addition, the diversity hypothesis from the S&T framework, suggests that with more diversity in work experiences, the scientists may form strong network ties. An empirical study by Lee and Bozeman (2004) found that diversity of experience was associated with increased collaborations. It may be reasonable that scientists who have a higher percentage of publications those that others regard as interdisciplinary have more diversity in work experience and may form strong collaborative relationships. Also, many of the grants require interdisciplinary work in which both ego and alter may form multifaceted collaborative relationships. Therefore, we hypothesize,

H6: Interdisciplinary publication will be positively related with multifaceted collaborative relationship

Data, Measures and Methods

Data: The data for this paper comes from the first stage of a large three-year study of social and collaborative networks of scientists[1]. The multi-year effort includes a large national two-stage survey of academic scientists. The survey is unique in that it captures the structure of collaborative and advice networks that are not accessible through existing data. The data uses an egocentric network study design to collect network data, which explores the relations around each sampled person.

The survey included three major categories of questions. First, the most extensive of these questions was a series of name generators and name expander questions based on research methods typical to sociological studies of social networks. The name generator questions were used to identify key collaborators or advisors in several key categories, including formal as well as research advice networks. While the name generators are useful for identifying collaborators, it was important to understand characteristics of these individuals especially from the standpoint of this paper. To do this, a series of name expander, questions were used to capture the nature of the collaboration (nature of research product), details of the

[1] Data analyzed in this paper were collected under the auspices of the 2005-2008 project, "Women in Science and Engineering: Network Access, Participation, and Career Outcomes"(NETWISE, 2007), a projet funded by the National Science Foundation(Grant #REC-0529642) (Co-PI's Dr. Julia Melkers and Dr. Eric Welch).

level of relationship such as strength of relationship, and length of relationship, and general demographics.

The survey was implemented online using saw tooth software. Individuals were alerted to the survey via personal emails and provided with a unique user id and password. Three reminders were sent, with a combination of email and post card reminders. One of the advantages of conducting the survey online is that questions could be electronically branched depending on respondent characteristics (e.g. faculty rank). The survey sample was drawn from the population of academic scientist in six discipline in Carnegie designated Research I universities.

Measures

The primary interest in the modeling section is to determine what social capital and S&T human capital factors affect multifaceted collaborative relationships. Specifically, the dependent variable in our study is multifaceted collaborative relationship. Four possible measures of collaborative multifaceted relationship can be constructed, 1) relationship count, 2) discrete multifaceted relationship (1/0), 3) average multifaceted relationship per ego, 4) discrete average multifaceted relationship per ego. For this paper, however we use, multifaceted relationship count, and discrete multifaceted relationship (1/0). Relationship count is operationalized by counting the number of collaborative activities between egos and alters in the collaborative relationship at the tie level. The collaborative activities are: collaboration on a grant proposal, collaboration on a conference paper, collaboration on a journal article, collaboration on product development, and collaboration on patent application. Discrete multifaceted relationship is operationalized by coding 1 and 0, "1" when counts of collaborative activities is greater than 1, and "0" when counts of collaborative activities is 1.

Strong ties are measured by the question: In the past academic year, how frequently were you in personal contact with these individuals (1=less often, 2=about monthly, 3=about weekly, 4=At least daily). Proximity is measured by the question: over the past two academic years, who have been your closest research collaborators outside of your institution (including other academic institutions, government and industry. Length of relationship/temporal embeddedness is measured by the question: How long have you known the individuals you named (1=less than 3 years, 2=3-6 years, 3=more than 6 years). For homophily of gender, and rank, we created variable: ego female* alter female (ties in which both ego and alter were females), similarly, for rank, we created variable: ego associate*alter associate, and ego full professor*alter full professor (ties in which both ego and alter are of the same rank).

Among the S&T human capital variables, interdisciplinary publications is measured by the question, approximately what percentage of your publication would others in your discipline recognize as interdisciplinary. Lab affiliation is measured by the question are you a member or have a formal affiliation with a permanent science or engineering lab or center (1= yes, 0=no). We use discipline/field, publication productivity, and rank (Associate professor, full professor) as our control variables.

Methodology:

Multilevel analysis or hierarchical linear modeling can be viewed as a modified version of multiple linear regressions designed to deal with data with a hierarchical nested structure (Duijn et al, 1999). This nested structure of the data is common to many sample designs where the data cannot be assumed as an independent observation. One such nested structure occurs in the study of personal networks, where ties are nested within the egos or respondents. Studies by Marijtje Duijn and colleagues (1999), Sniders and colleagues (1995), have analyzed social network data, in which ties are nested within egos using hierarchical linear modeling technique. The aim of this paper is to expand on these previous works and to give an illustration of the usefulness of hierarchical modeling for ego-centered networks. The hierarchical linear model is appropriate when a relational variable such as tie strength is the dependent variable (Duijn et al, 1999). In our study, the dependent variable is a collaborative relationship between egos and alters. More specifically, our dependent variable is multifaceted collaborative relationship between egos and alters in an academic context. Multifaceted collaborative relationship refers to a collaborative relationship in which the egos and alters are engaged in a number collaborative activities such as collaboration on a grant proposal, collaboration on a conference paper, collaboration on a journal article, collaboration on product development, and collaboration on patent application. The ties or relations, ego-alter pairs are "level one" units, and egos are the "level two" units.

We analyzed the data using hierarchical linear modeling (HLM) (Raudenbush and Bryk, 2002) with the statistical package HLM 6. This analytic technique is particularly well suited to egocentric network studies as it accounts for the inherent nesting in the data. With HLM, we first estimate "level one" parameters describing the relationship between predictor and outcome variable. At this lower level, we are using characteristics of relationships (e.g., strength and length of relationship), homophilous relationships (similar rank, and gender) to predict multifaceted collaborative relationship. Once fitted, the intercept and slopes estimates in the "level one" model become the outcome variables for the "level two" analysis.

The multilevel/hierarchical model:

The regression equation at the "level one" is:
Equation 1: "level one" model:
$Yij=\beta_{0j}+\beta_1$(strength of relationship)$+\beta_2$(length of relationship)$+\beta_3$(Alter female)$+\beta_4$(Alter friend) $+\beta_5$(Ego female*Alter female) $+\beta_6$(Alter outside of ego's institution) $+\beta_7$(Ego associate*Alter associate) $+\beta_8$(Ego full*Alter full) $+R_{ij}$

Equation 2: "level two" model:
$\beta_0=\gamma_{00}+\gamma_{01}$ (Full professor) $+\gamma_{02}$ (Associate professor) $+\gamma_{03}$ (Publication interdisciplinary percent) $+\gamma_{04}$ (Publication average) $+\gamma_{05}$ (Formal affiliation with a lab) $+\gamma_{06}$ (Physics) $+\gamma_{07}$ (Biology) $+\gamma_{08}$ (Chemistry) $++\gamma_{09}$ (EAS) $+\gamma_{010}$ (CS)
This hierarchical level model is formulated for the dependent variable *Yij*, e.g. .multifaceted collaborative relationship *i* of respondent *j* with independent variables at the first level, x*ij,* e.g., strength of ties and so on., at the second level, *zj* , e.g. , respondent's interdisciplinary percentage and so on.

Table 1: Descriptive Statistics

Variable name	n	Mean	Standard Deviation
Relationship/tie level			
Alter female	5765	0.18	0.39
Ego alter female	5765	0.11	0.32
Alter friend	5765	0.26	0.44
Length of relationship	5749	2.38	0.73
Strength of relationship	5672	2.30	0.98
Alter outside of ego's institution	5765	0.52	0.50
Ego assoc *alter assoc	5765	0.05	0.23
Ego full *alter full	5765	0.12	0.33
Multifaceted Relationship count	5765	1.70	0.95
Multifaceted Relationship discrete	5468	0.54	0.50
Ego level			
Full Professor	1111	0.44	0.50
Associate Professor	1111	0.28	0.45
Publication interdisciplinary percent	1111	36.98	34.65
Publication average	1111	3.89	5.43
Formal affiliation with a lab	1111	0.22	0.42
Physics	1111	0.18	0.39
Biology	1111	0.19	0.39
Chemistry	1111	0.20	0.40
CS	1111	0.14	0.35
EAS	1111	0.19	0.39
EE	1111	0.10	0.30

Descriptive statistics indicate that the average length of ties is around two and half years. In other words, on an average, both ego and alter have known each other for around two and half years. Similarly, the average frequency of interaction is 2.3, i.e. frequency on interaction between ego and alter is more than once a month and less than once a week. More specifically, the average frequency of interaction of the ties is around once in two weeks. An average of 26% of the ties is friendship ties. The average percentage of ties in which alters is a female is 18%. 11% of the ties are homphilous by gender i.e. both ego and alter is a female. The average percentage of ties in which respondent's collaborators is outside of their academic institution is 52%. The average percentage of ego alter pair or ties in which both ego and alter is a full professor is 12%. An important finding is that 54% of ties or collaborative relationships have more than one collaborative activity going on between them.

The survey was administered to six fields of science and engineering: physics, chemistry, biology, earth and environmental science, electrical engineering, and computer science. In this sample, 18% of scientists are from physics, 19% from Biology, 20% from chemistry, 14% from computer science, 19% from earth and environmental science, and 10% of the scientists are from electrical engineering. Associate and Full professors make up 28% and 44% of the respondents respectively. 22% of the respondents reported having affiliation

with a lab. The average percentage of articles that others would consider to be interdisciplinary is almost 37%. We present the HLM findings in the next section.

T**able 2: Hierarchical Linear Model Results**

Relationship Level	**Discrete Collaborative multifaceted Relationship (1/0)**	**Multifaceted collaborative Relationship Count**
	Model 1	**Model 2**
Intercept	0.14(0.04)***	0.50(0.01)***
Alter female	0.30(0.10)***	0.08(0.02)***
Ego alter female	-0.37(0.14)***	-0.09(0.03)***
Alter friend	0.31(0.08)***	0.04(0.01)***
Length of relationship	0.21(0.05)***	0.07(0.01)***
Strength of relationship	0.63(0.04)***	0.18(0.01)***
Alter outside of ego's institution	0.33(0.07)***	0.09(0.01)***
Ego assoc *alter assoc	-0.15(0.13)	-0.01(0.03)
Ego full *alter full	-0.20(0.10)***	-0.03(0.02)**
Ego level		
Full Professor	0.28(0.10)***	0.09(0.02)***
Associate Professor	0.25(0.11)**	0.07(0.02)***
Publication interdisciplinary percent	0.00(0.00)***	0.00(0.01)***
Publication average	0.01(0.00)***	0.00(0.01)***
Formal affiliation with a lab	0.17(0.10)***	0.08(0.02)***
Physics	-0.28(0.16)**	-0.08(0.04)***
Biology	-0.70(0.15)***	-0.22(0.04)***
Chemistry	-0.38(0.15)***	-0.14(0.04)***
CS	0.00(0.16)	-0.02(0.04)
EAS	-0.34(0.15)**	-0.13(0.04)***
Level 1 variance		0.14
Level 2 variance		0.04

* p<0.10; ** p<0.05; ***p<0.01

Model 1: Discrete multifaceted relationship as function of alter level variables and ego level variables
Model 2: Multifaceted collaborative count as a function of alter level variables and ego level variables

HLM Findings:

We found strong support for relational network characteristics. Strength of relationship and length of relationship is significantly associated with multifaceted collaborative relationship. In other words, multifaceted collaborative relationship is strongly predicted by strength of relationship and length of relationship (p<0.001). Expressive relationships are positively associated with multifaceted collaboration. Friends are more likely to engage in a number of

collaborative activities. Therefore, we conclude that "closeness" of relationship is positively associated with multifaceted collaborative relationship (H1).

Physical proximity is negatively related to multifaceted collaborative relationship. Going by the logic of diversity hypothesis of S&T human capital perspective, higher diversity of contacts leads to increased collaboration. It may be reasonable to assume that scientists with diverse contacts outside of their institutions form strong relationships with those contacts, leading to multifaceted collaborative activities.

Homophily of rank in that when ego and alter both are full professors (ego full professor*alter full professor) is significantly related to multifaceted collaborative relationship, but the direction of the association is negative in contrast to our proposed hypothesis (H3). Collaborative Relations/ties, which have both ego and alter as full professors is less likely to be multifaceted. It may be reasonable to assume that full professors may be engaged in a wide variety of activities such as collaboration, advising and supervising PhD students and junior faculty members, and other administrative activities. It may seem possible that full professors will engage in multifaceted collaborative relationships with junior faculty members.

Our hypothesis that homophily of gender will be negatively related to multifaceted collaborative relationship is strongly supported (H4). In other words, homophily of gender (Similarity of gender) is negatively associated with multifaceted collaborative relationship. Specifically, collaborative relations ties in which both ego and alter are females is less likely to be multifaceted. In other words, female faculty members are less likely to collaborate with other female faculty on a number of collaborative activities. This finding supports the argument that women differentiate their choice in seeking out for resources. In other words, women seek instrumental resources from men and social support and expressive resources from women. It may be possible that women scientists do not collaborate much with other women scientists. This has some consequences for women such as abundance of weak ties. More specifically, women have a large number of weak that may not be multifaceted.

Among the S&T human capital factors predicting multifaceted collaborative relationships, interdisciplinary publication is positively associated with multifaceted collaborative relationship (H5), after controlling for productivity and rank. In other words, scientists who have a higher percent of work that other consider as interdisciplinary are more likely to engage in a large number of collaborative activities in a collaborative relationship. This finding seems to indicate that interdisciplinary work exposes faculty to large collaborative networks that provide opportunities to engage in multifaceted collaborative relationship. Scientists who are affiliated to a federal lab are more likely to have a multifaceted collaborative relationship (H6). Affiliation to a lab adds to researchers experience and size of collaborative network. In addition, large collaborative networks may increase the diversity and breadth of experience. An empirical study by Lee and Bozeman (2004) found that diversity of experience was associated with increased collaborations. It may be reasonable that scientists who are affiliated to federal labs experience more diversity in work experience and may form strong collaborative relationships involving a large number of collaborative activities.

Conclusion:

With this paper, we seek to contribute to the stream of literature on collaborative relationships. The relational aspect of social network and S&T human capital factors are important in collaborative relationships. In particular, strength and length of relationships strongly predict multifaceted collaborations, i.e., relationships that involve a large number of collaborative activities. More specifically, stronger and longer relationships are more likely to be multifaceted. Expressive relationships, friendships strongly predict multifaceted collaborative relationship. Scientists who are friends with each other are likely to engage in a number of collaborative activities with each other.

A collaborative relationship in which both ego and alter are females is less likely to involve more than one collaborative activity. This finding further strengthens Ibarra (1992) that women have fewer strong ties with women. S&T Human capital factors, such as affiliation to a federal lab, and publication interdisciplinary percentage strongly predict multifaceted collaborative relationships and are positively associated with multifaceted collaborative relationship. Our findings on human capital factors indicate that a higher breadth of experience, such as engaging in interdisciplinary work, and affiliation to a lab increases the likelihood of multifaceted collaborative relationships.

This paper studies predictors of multifaceted collaborative relationships at two levels of analysis—an important advance in our understanding of multifaceted relationships. Our use of HLM has allowed us to develop a better understanding of multifaceted collaborative relationships. The paper addresses an important question, not only from the point of view of theory but also policy and practical guidance to men and women scientists. For example, each of the relational attributes of social network as well as represents an opportunity for scientists in an academic setting to develop multifaceted collaborative relationships. We hope to see further research delving into the consequences of multifaceted collaborative activities.

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