Effects of Collaborative Networks on Satisfaction of Academic Scientists and Engineers

BY

YAMINI JHA
B.A., Delhi University, 1998
M.A., Delhi University, 2000
M.A., School of Planning and Architecture, Delhi, 2002

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Defense committee

Eric Welch, Chair and Advisor
Timothy Johnson
Karen Mossberger
Julia Melkers, Georgia Institute of Technology
Karl Rethemeyer, University of Albany

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1. INTRODUCTION AND IMPORTANCE OF THE STUDY

1.1. Background

This dissertation studies the effects of collaborative networks on satisfaction of academic scientists in six fields of science and engineering. Scientists collaborate in order to enhance their knowledge and skills, in order to obtain to funding for research, in order to access complex methodologies and equipments and so on (Katz and Martin, 1997; Melin, 2000). Scientists also cite that collaboration makes research fun and reduces isolation (Fox and Faver, 1984; Melin, 2000). According to Rijnsoever and colleagues (2008), scientists collaborate as they expect collaboration to result in rewards and recognition. Specifically, when scientists collaborate, they exchange knowledge for recognition. Satisfaction results when expectations of rewards and recognition are met. Not all collaborative exchanges result in rewards and recognition, and consequently satisfaction. Depending on the social structure within which the collaborative exchange takes place, strength of the collaborative exchange relation, status of the collaborator, and resources received from collaborators, some collaborative exchange may lead to greater rewards and recognition, and consequently higher levels of satisfaction compared to others. However, such structural explanations of satisfaction are incomplete without taking into account the underlying social mechanisms or processes that link structure to rewards, and consequently to satisfaction. Specifically, social mechanisms are underlying social processes that link networks and satisfaction. This dissertation elaborates the role of several unobserved social mechanisms that link four collaborative network properties—1) collaborative network constraint, 2) strong collaborative ties, 3) superiority of collaborators in terms of seniority and grant getting ability, 4) resources received from collaborators to rewards and recognition, and consequently to satisfaction.

Research on work satisfaction among academic faculty has surged in the past several decades. Reasons for this scholarly interest are the positive impacts of satisfaction on research productivity and organizational effectiveness (Rosser, 2004, 2005; Johnsrud and Rosser, 2002). Another reason for this scholarly interest is the association of satisfaction with job turnover. Higher levels of satisfaction lead to low job turnover because the satisfied faculty member is motivated to work where his or her expectations are met. Several determinants have been used to explain work satisfaction among faculty members such as collegial relationships, rewards and recognition, receipt of organizational resources, gender, race, rank, disciplinary context among others (Bilimoria et al, 2006; Callister, 2006; Sabharwal and Corley, 2009; Ambrose et al, 2005; Seifert et al, 2008, Wharton et al, 2000; Bozeman and Gaughan, 2011). Although, faculty member's relationship with their colleagues and the need to gain recognition from them is a constant theme in the satisfaction literature within the academic context, little attention has been given to understand the effects of structure of those relationships on satisfaction. This dissertation provides an opportunity to enhance our understanding of the effects of collaborative networks on satisfaction of academic scientists, and thus makes a valued contribution to the research collaboration literature, satisfaction literature, and social network literature.

Findings from this dissertation may have implications on organizations more generally. Work satisfaction is emerging to be one of the most researched topics in organizational studies. Previous studies have shown that actors occupying structurally powerful locations in networks are more satisfied than others (Shaw, 1964). Others have found that actors with more number of ties are more satisfied compared to those with fewer ties (Roberts and O'Reilly, 1979). Most of the organizational research on the effects of networks on satisfaction investigates the effect of either one or two aspects or properties of networks on satisfaction. By investigating the effects of four network properties on satisfaction, and hence the knowledge developed in this dissertation may inform organizational actors –public, private or nonprofit such that they may be able to influence their work satisfaction by strategically shaping their networks.

1.2. Overall concept and objective of the study

The concept of satisfaction, from the theoretical tradition of expectancy theory of motivation is based on two ideas: rewards and expectations (Locke, 1969). Specifically, when an individual reports a higher level of satisfaction, he or she is saying that that their reward expectations are met. Attainment of rewards and recognition is one of the primary motivations of academic scientists. In order to attain rewards and recognition, they engage in collaborative exchange with other colleagues. Some collaborative exchanges depending on the network structure may result in greater levels of rewards and recognition and thus are more satisfying than others.

The setting for this research is academic science and the subjects of this research are individual academic scientists. The ultimate objective of this research is to determine the extent to which four collaborative network properties-- collaborative network constraint, strong collaborative ties, superiority of collaborators in terms of seniority and grant getting ability, resources received from collaborators affect academic scientist's satisfaction with rewards as well as satisfaction with reputation of department and institution through the mediating influence of rewards and recognition. In other words, the objective is to study the indirect effects of four collaborative network properties on satisfaction of academic scientists. This dissertation also recognizes that collaborative network properties may directly affect satisfaction through perceptions of one's ability and the work situation more generally. To study the effects of collaborative network properties on satisfaction, an integrated theoretical framework including network theoretical perspective, social exchange theory, social mechanisms, and expectancy theory of motivation is developed, tested, and findings are reported. The findings provide insight into the importance of collaborative networks on satisfaction of academic scientists.

1.3. Importance of the dissertation

This dissertation makes several important contributions. First, it recognizes the similarity between research collaboration and social exchange. The basic idea of social exchange theory is that actors are mutually dependent on each other to accomplish goals they cannot achieve on their own. The goal of the actors engaged in social exchange is to generate rewards, recognition, and valued goods that provide each other with more benefits than otherwise (Molm, 1991; Emerson, 1976). Scientists in collaborative exchange relationships are mutually dependent on one another such that the scientist provides knowledge to the collaborator and in turn receives rewards and recognition. Although, previous research acknowledges that scientists collaborate to gain recognition, this literature is largely descriptive. In conceptualizing research collaboration among scientists as social exchange and integrating it with social network structural perspective to explain rewards and recognition, and consequently satisfaction, this dissertation makes a valued contribution to the research collaboration literature.

Second, this dissertation observes that social exchange theorists and network structural theorists both view social structure as a configuration of exchange relations involving the exchange of valued items (material, informational, symbolic) (Cook and Whitmeyer, 1992; Molm, 1991, 2000; Lawler and Thye, 2006). Hence, this research finds it appropriate to analyze exchange relations as social network relations and apply network concepts to understand the effects of social exchange relations on outcomes such as rewards and recognition attained by academic scientists. This dissertation explains that certain exchange relations may provide more valued outcomes or rewards than others. For example, in close exchange relations, actors' expectation of reciprocity spurs the initial giving, and thereafter receiving of valued resources. (Plickert et al, 2007). By observing that social exchange theory and social network structural perspective have similar views on social structure and integrating them to explain the effects of collaborative exchange relations on rewards, and consequently satisfaction, this dissertation makes an important contributions to the social network literature, and research collaboration literature.

Third, this dissertation integrates three theoretical perspectives—social networks, social exchange theory, and expectancy theory of motivation to explain the effects of collaborative networks on satisfaction of academic scientists. Specifically, this integrated framework explains that when academic scientists collaborate, they exchange knowledge for rewards and recognition, and fulfillment of rewards and recognition leads to higher levels of satisfaction. However, all collaborative exchange relationships may not result in rewards and recognition, and consequently satisfaction. Depending on network structure, characteristics of ties, status of alters, and resources received from them, some collaborative exchange may lead to more rewards and recognition than others, and therefore higher levels of satisfaction. Integration of three theories results in a robust and comprehensive model of the effects of collaborative networks on satisfaction through the mediating influence of rewards and recognition.

Fourth, this dissertation recognizes that collaborative networks can lead to satisfaction directly as well as indirectly. For example, egos' located in constrained network structures form negative perceptions about their capabilities of attaining rewards and recognition because they perceive being socially less valued, less legitimate, and controlled by a structurally powerful collaborators, and as a result their satisfaction levels are lower. Further, networks can lead to satisfaction indirectly through the mediating influence of rewards and recognition. By recognizing the two routes through which collaborative networks lead to satisfaction, this dissertation contributes to the social networks and satisfaction literature.

Fifth, this dissertation recognizes and discusses the role of underlying social processes or mechanisms that link network structures and satisfaction. The six social mechanisms discussed in this dissertation research are 1) social control, 2) legitimacy, 3) access, 4) reciprocity, 5) sense of personal control, and 6) validation and resource efficiency. These social mechanisms link the four network properties to reward outcomes and consequently satisfaction. However, social mechanisms are not universal laws that can be applied to each network property. For example, while certain social mechanism may link network constraint to rewards and consequently to satisfaction, they may not link other network properties such as strong ties to satisfaction. In other words, social mechanisms are structure specific. In taking a social mechanisms approach to understanding the relationship between networks, rewards, and satisfaction, this dissertation makes an important theoretical contribution to the emerging analytical social science literature.

Sixth, this dissertation integrates four network properties—network constraint, strength of ties, status of the alter, and resources received from alters. These four network properties focus on different aspects of networks. Network constraint focuses on the pattern of connection between alters. Strength of ties focus on the nature of ties, Status of alters refers to the superiority of alters in terms of expertise, seniority, and skills. Resource received from alters focuses on the desirable resources that the ego receives from alters which helps the ego achieve career goals. An integration of these four network properties is possible because they are distinct and focus on different aspects. By integrating the four network properties, this dissertation presents a holistic picture of networks, and enhances our understanding of the effects of networks on satisfaction.

Seventh, this dissertation recognizes that previous studies often focus on the positive role of networks and neglect the fact that networks sometimes have negative effects on the ego level outcomes. This research looks at the dark side of social networks by recognizing that network constraint may lead to lower levels of satisfaction. Specifically, in a constrained network structure, the ego is dependent on a structurally powerful alter, and have lower access to resources, and may not be able to attain rewards, and consequently report a lower level of satisfaction. The structurally powerful alter may also be controlling, and may withhold rewards and recognition from the ego. As a result, the ego may perceive to be less legitimate, less valued, and hence may not be able to fulfill his or her reward expectations. By recognizing the dark side of networks, this dissertation makes a contribution to the social network literature.

Lastly, this dissertation includes two kinds of satisfaction—satisfaction with rewards and satisfaction with the reputation of department and institution. These two kinds of satisfaction represent two very different aspects of satisfaction. Satisfaction with rewards is more concerned with perceptions of one's own professional success, and the other that is concerned with perception of one's department and institution. Additionally, this dissertation recognizes that collaborative network factors may not contribute similarly to both kinds of satisfaction.

1.4. Survey data and research methods

The data for this dissertation comes from a two phase national survey of academic scientists and engineers in Research I universities in the United States. The survey collected data at two points in time on demographics, individual background, collaborative networks, salary, dollar amount of largest grant received, awards, satisfaction, productivity, resources received from the department, department size, and number of courses taught. The primary motivation of this two phase national study is to understand how and why networks matter for career outcomes of academic faculty in six fields of science and engineering.

The survey instruments collected network data using a series of *name generator* and *name interpreter* questions. Name generator questions asked respondents to write the names of closest collaborators within and outside of their own university. Once the survey respondent provided names of their closest collaborators, the names were piped forward into a series of name interpreter questions, for which the respondent was asked to respond to details about the level of their relationship with the collaborators. For example, respondents were asked about their interaction frequency with the collaborators, duration of their interaction with the collaborators, whether or not collaborator was a close friend. Further, respondents were also asked whether the collaborator was a junior, senior or peer, and whether the collaborator introduced the ego scientists to other potential collaborators or nominated the ego scientists for awards or invited the ego scientist as a speaker. Alter-level data are converted to respondent attribute data through the aggregation of mean or sum values within an individual's network, depending on desired variable structure. Although, the survey asked question about advice ties, but for the purposes of this dissertation research, details about collaborative networks are included only.

In the first phase survey in 2007, 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 disciplines in Carnegie-designated Research I universities (150 universities). This first phase of survey resulted in 1577 usable responses. The second survey was conducted in 2010. The purpose of this second survey was to gather longitudinal data from ego scientists who responded to the first survey in 2007. Of particular importance was to get updates on the following information: rank and tenure, work satisfaction, salary, dollar amount of largest grant received, and networks. This dissertation uses data from both points in time. The two year panel data enables analysis on how collaborative network structure in 2007 affect rewards and recognition, and satisfaction in 2010. The population for the second survey was derived from the respondents of the 2007 phase I ego survey. Matching the 2007 and 2010 survey responses resulted in a final panel of 765. Due to listwise deletion, primarily because of missing data in the dependent and independent variables, the final sample sizes used in this dissertation study are lower than 765. Nevertheless, descriptive results for the sample used in this study are not significantly different from the full panel of 765 responses.

The first step in the methodology section is univariate and bivariate analysis. Univariate statistics describes and summarizes individual variables. It looks at the range of values and central tendency (mean, median, and mode) of the variables. Bivariate statistics compares two variables. Specifically, it is helpful in examining the association between two variables. The next step is to run an ordinary least square regression to predict satisfaction with rewards, and satisfaction with reputation of department and institution. This study takes a step further by conducting structural equation modeling because of the complexity of the theoretical model, presence of multiple independent and dependent variables, and the effect of independent variables on the dependent variable through mediator variables. Structural equation models are run with and without imputing for missing data for both of the dependent variables—satisfaction with rewards and satisfaction with reputation of department and institution.

1.5. Structure of the Dissertation

This dissertation is organized into six chapters. Chapter two explains the concept of satisfaction from the theoretical tradition of expectancy theory of motivation. Specifically, this chapter explains that satisfaction results when expectations of rewards and recognition are met. After defining the concept of satisfaction in terms of rewards and expectations, it reviews literature on satisfaction in academic settings particularly academic science settings. Literature review reveals that satisfaction among academic faculty results when their expectations of rewards and recognition are met. Attainment of rewards and recognition is one of the primary motivations of academic faculty in science. Academic scientists collaborate as they expect collaborative relationships to result in rewards and recognition. Collaborative relationships thus resemble social exchange—scientists exchange knowledge for knowledge and recognition. Empirical research reviewed in this chapter indicates that collaborative relationships represent potential for rewards and recognition, for example, resources received from collaborative relationships, and collaboration with seniors enhances scientist's recognition, and validates his or her credentials. Then, the literature review chapter discusses satisfaction as a multidimensional concept, and identifies gaps in the existing theoretical framework. Specifically, two dimensions of satisfaction—satisfaction with rewards and satisfaction with reputation of department and institution are discussed. Although, the existing theoretical frameworks include collegial relationships to predict satisfaction, little attention has been given to understand the role of structure of those relationships on satisfaction. This dissertation provides the opportunity to understand in depth the effects of the structure of collaborative relationships on satisfaction. Next, this chapter situates structure of interpersonal relationships within the social network theoretical tradition. Four network properties—network constraint, strength of ties, status of alters, and resources received from alters is discussed. Further, this chapter recognizes that four social networks properties link satisfaction through underlying social mechanisms or processes.

Chapter three extends the social network and social mechanism theoretical framework and integrates it with social exchange theory, and expectancy theory of motivation to develop an integrated theoretical model explaining the effects of collaborative networks on satisfaction. This integrated theoretical framework explains that networks factors such as constraint, strong ties, superior alters, and resources received from alters via certain social mechanisms or underlying processes lead to outcomes such as rewards and recognition. Satisfaction results when expectations regarding rewards and recognition are met. Specifically, networks via social mechanisms indirectly affect satisfaction through the fulfillment of rewards and recognition. Within the context of academic science, this integrated framework explains that when scientists collaborate, they exchange knowledge for recognition, and fulfillment of recognition expectations lead to satisfaction. Not all collaborative relationships lead to rewards and recognition. Depending on the network structure within which the collaborative exchange takes place, strength of the collaborative exchange relation, status of the collaborator, and resources received from the collaborators, certain collaborative exchanges may result in greater levels of rewards and recognition compared to others. Four testable hypotheses for each of the four network properties are developed from this integrated framework. For each of the hypotheses, the role of social mechanism linking that particular network property to satisfaction is highlighted. Each hypothesis is linked to prior empirical and theoretical literature. Additionally, four propositions on the relationship between the network properties are also developed.

Chapter four describes the survey data collection procedure. Then, it describes the measures, including the measurement characteristics, appropriateness, reliability of each of the measures. Further, this chapter also provides a discussion on the pattern and extent of missing data and techniques for handling missing data. Specifically, this chapter discusses two techniques that were adopted to find the pattern of missing data. First, creation of missing data dummy code (missing value=0; non missing value=1), and correlating it with other variables in the dataset. Correlation findings suggest that none of the recoded dummy network variables were significantly correlated with the satisfaction and reward variables, suggesting that the missing network data are completely at random. The second technique involved creating a missing data code again and computing t test comparisons between respondents and non-respondents to examine whether they are different on any of the variables in the data set. T test comparison suggested that scientists who responded to both kinds of satisfaction did not differ significantly in their network characteristics and rewards compared to scientists who did not respond to both kinds of satisfaction, indicating that the missing data on the satisfaction variables are completely at random, and may be retained and treated. Next, this chapter suggests that regression imputation should be used to impute for missing data as this technique strives to methodologically estimate the missing data and is more accurate and objective than other techniques (Tabachnick and Fidell, 2001; Raymond and Roberts, 1987). In the end, this chapter discuses structural equation modeling and the justification of this research methodology in the context of this research.

Chapter five reports findings from univariate and bivariate analysis. It also reports findings of OLS regression and four structural equation models. Structural equation models are run with and without imputing the missing data on the two satisfaction variables—satisfaction with rewards and satisfaction with reputation of department and institution. Support, no support, or reverse support for hypotheses and propositions are indicated through the findings. Wherever possible, the relation of findings to broader conceptual and theoretical statements is discussed.

Additionally, findings are also discussed in terms of social mechanisms at work in linking the particular collaborative network property and satisfaction. Emphasis was placed to summarize the important findings for each structural equation model.

Chapter six provides a synopsis of the dissertation and further elaborates on the findings presented in chapter five by providing extended conclusions as well as theoretical and empirical contributions of this dissertation. Additionally, specific limitations of the study and future research directions are provided.

2. LITERATURE REVIEW

2.1. Introduction

The impact of interpersonal professional relationships on individual outcomes is increasingly gaining interest among social scientists (Agneessens and Wittek, 2008; Flap and Volker, 2001). Moreover, increased collaboration consistent with changing institutional realities requires individuals to work in teams, to develop interpersonal skills, to process complex information, and to value individual differences (Baldwin and colleagues, 1997). As a result, individuals are more and more dependent on their relationships with each other for successful performance, for attaining rewards and recognition, satisfaction and so on. In this context, Flap and Volker (2001), Hurlbert (1991), and Baldwin and colleagues (1997) have examined the impact of structure of interpersonal environment on satisfaction. However, several scholars argue that such structural explanations of satisfaction are incomplete (Agneessens and Wittek, 2008). They suggest that models that link network structure and outcomes need a better micro foundation which will not only provide detailed analyses of network structure but also specify underlying processes triggered by the network structure. This approach is the social mechanism approach in analytical social science. Social mechanisms are underlying social processes that link networks and satisfaction. This dissertation utilizes the social mechanisms approach to understand the relationships among 1) four network properties: network constraint, strong ties, superiority of ties, and resources received from ties, 2) rewards and recognition, and 3) consequently satisfaction of academic scientists and engineers. The focus of this chapter is to provide a review of literature on the impacts of networks on satisfaction both generally and in academic science settings.

This chapter is organized into five sections. The first section defines and discusses the importance of work satisfaction. As will be evident in the paragraphs below, most of the definitions focus on two core ideas: rewards and expectations. Specifically, satisfaction results when reward expectations are met. Satisfaction is explained through an integration of expectancy theory of motivation and social network theoretical perspective. Specifically, certain network structures and tie characteristics provide access to valuable resources, which helps the individual attain rewards and professional recognition. Satisfaction results when reward expectations are met. After discussing satisfaction in a generic way, this study turns to discussing satisfaction within academia, particularly in academic science and engineering. The definitions, determinants, dimensions of satisfaction, and gaps in the existing theoretical frameworks used to explain satisfaction in academia are discussed in the second section. Attainment of rewards and recognition is one of the primary motivations of faculty within academia. Faculty form and participate in collaborative networks which provides them rewards and recognition, and consequently satisfaction. Specifically, collaboration resembles social exchange—faculty provides knowledge to their collaborators and in return receives knowledge, recognition, rewards, and consequently satisfaction. The third section discusses the concept of networks and the empirical evidence linking networks and satisfaction. In the fourth section, the role of social mechanisms in linking networks and satisfaction is discussed. A total of six social mechanisms are introduced and briefly discussed in this section. The summary of the chapter is provided in the fifth section.

2. 2. Satisfaction: A general overview

The concept of work satisfaction and its determinants have occupied a prominent place in the social science literature for several decades. One of the main reasons for this scholarly interest is the association of satisfaction with job turnover. Previous research suggests that high satisfaction leads to low job turnover because the satisfied individual is motivated to work where his or her expectations are met (Lawler and Porter, 1967; Deci and Ryan, 1984). Another reason for the popularity of the concept stems from the notion that work satisfaction may have consequences for the overall well-being of the individual in terms of physical and mental health, and satisfaction with life in general (Flap and Volker, 2001; Lawler and Porter, 1967; Hurlbert, 1991).

According to the expectancy theory tradition, when an individual reports a higher level of satisfaction, he or she is in fact saying that their rewards and recognition expectations are met as a result of the activity they engaged in. Kalleberg (1977) and Locke (1969) also agree that satisfaction is closely affected by the amount of rewards people derive from their work. Specifically, Kalleberg (1977) and Locke (1969) define work satisfaction as a positive mental state resulting from evaluation of one's work. Mottazl (1986) defined satisfaction as a function of what is expected and what is met. If individuals perceive that their expectations are met or likely to be met, they experience a higher level of satisfaction. Some have defined satisfaction as the disparity between what the employees desires from a job and what he or she actually receives from it (Scarpello and Vandenberg, 1992; DeLeon and Taher, 1996). Hurlbert (1991) defines satisfaction as an intangible reward outcome affected by perceptions about work.

Several determinants have been used to explain work satisfaction among individuals such as socio demographics, job characteristics, and recognition from colleagues. There seems to be no difference in work satisfaction between men and women, although women are generally paid less for doing work similar to men (Weaver, 1978; Witt and Nye, 1992; Mottaz, 1986). Job autonomy has been found to promote work satisfaction (Fried and Ferris, 1987; Currivan, 2000). The degree to which an individual exercises discretion over the performance of job tasks is autonomy. With more autonomy, individuals feel a sense of accomplishment, and report a higher level of satisfaction. Other job characteristics such as task clarity have also been found to lead to higher levels of satisfaction (Fried and Ferris, 1987; Ting, 1997). Task clarity refers to the degree to which the job tasks are clearly communicated to the individuals. Previous research has shown that an accurate understanding of the job helps individuals adjust to their jobs by reducing uncertainty, and thereby leads to higher levels of satisfaction (Ting, 1997). In addition to job characteristics, recognition from supervisors and colleagues lead to greater levels of satisfaction (Mitchell, 1982; A. B. Sousa-Poza and A. A. Sousa-Poza, 2000; Clark and Oswald, 1996; Kreps, 1997).

In the above paragraphs, definitions and determinants of satisfaction are discussed. Is satisfaction among academic faculty determined by the same general factors as discussed above? For example, does academic faculty member's satisfaction get affected by recognition from colleagues as it does in the general context? Do definitions of satisfaction within the academic context draw from the general literature? In the following paragraphs, this study discusses satisfaction among academic faculty, particularly within science and engineering.

2.3. Satisfaction in the academic context: Definitions and determinants

Research on work satisfaction among academic faculty has surged in the past several decades. Work satisfaction within academic context has been found to positively impact research productivity, turnover, and organizational effectiveness among others (Rosser, 2004, 2005; Johnsrud and Rosser, 2002). Previous studies have found that faculty satisfaction is predicted by collegiality and collaboration, perceptions about the quality of work life, gender, ethnicity, rank, tenure, and disciplinary context (Bilimoria et al, 2006; Callister, 2006; Sabharwal and Corley, 2009; Ambrose et al, 2005; Seifert et al, 2008, Wharton et al, 2000).

Olsen (1993) in her study on faculty satisfaction adopted Locke (1969) and Kalleberg (1977) definition that satisfaction is a positive mental state resulting from fulfillment of what one wants from ones job. Previous research suggests that lower levels of rewards and recognition is associated with lower level of satisfaction and higher rates of turnover among academic faculty (Olsen, Maple, and Stage 1995; Caldwell et al, 1990; Chatman, 1989). Faculty members are motivated to attain rewards and recognition, particularly in academic science (Crane, 1965; Cole and Cole, 1967). Academic scientists work for peer recognition, and in the long run receive awards, grants, and rewards (Rijnsoever et al, 2008). Specifically, scientists collaborate with colleagues—give away their knowledge, and in return receive recognition. Recognition is thus a socially validated testimony that one has successfully lived up to the expectations or requirements of ones role as a scientist. Specifically, the social system of academic science rewards and recognizes those scientists who have contributed to the advancement of knowledge. Fulfillment of rewards and recognition has been found to lead to higher levels of satisfaction among academic faculty (Mamiseishvili and colleagues, 2011). Hagedorn (1994) also found reward and recognition as one of the primary sources of satisfaction among academic faculty. Although, not directly related to satisfaction but may be important to report that Gmelch and co-authors (1986) found that one of the most important factors in their faculty stress index is rewards and recognition.

2.3.1. Professional relationships and satisfaction within academia

Faculty member's relationship with their colleagues and the need to gain recognition from them is a constant theme in the satisfaction literature within the academic context. Several researchers have found that one of the most important sources of satisfaction among faculty was collegial relationships (August and Waltman, 1994; Bilimoria et al, 2006; Etzkowitz et al, 2000; Ambrose et al, 2003). Faculty members are satisfied when their colleagues are supportive, and are willing to listen and provide feedback on their ideas, proposals, and papers. Alternatively, faculty members report a lack of satisfaction when their colleagues lacked time or interest in faculty member's endeavors (Ambrose et al, 2005). Collegial relationships not only positively affect satisfaction but also provide information to faculty member about how to conduct their work, improve performance, and understand the political workings of the university system. Collegial relationships also provide faculty with opportunities for forming new professional relationships, and greater involvement and visibility in their professional discipline (Higgins, 2000; Higgins and Kram, 2001; De Janasz et al, 2003).

Barnes, Agago, and Coombs (1998) found “sense of community” as one of the most important predictors of work satisfaction and intention to leave the institution among academic faculty. Using data derived from 1989 Carnegie Foundation for the Advancement of Teaching questionnaire, Hagedorn (1994) tested a causal model across faculty at three stages of career experience: novices, midcareerists, and disengagers (those most proximate to retirement) and the results indicated that that regardless of career stage, perceived support from colleagues resulted in higher levels of work satisfaction. Others such as Herzberg and colleagues (1967) have also reported that the most common and consistent response to “what makes you most satisfied or most dissatisfied with your work” pertained to relationships with colleagues. Collegial relationships contribute significantly to feelings of career success regardless of rank or tenure status (Peluchette, 1993). In the following sub section, a particular kind of professional relationship—collaborative relationships are discussed with respect to satisfaction among academic faculty particularly in science fields.

2.3.2. Collaborative relationships and Satisfaction within academia

Academic science faculty are concerned about engaging with and obtaining approval and recognition from their colleagues (Bozeman and Gaughan, 2011). Fox and Faver (1984) find that although faculty members seek autonomy in the sense they exercise independent judgment in the theories and methods they use, they also cannot work in a social vacuum. Autonomy is contravened by the need to collaborate. Fox and Faver (1987) found that collaboration reduces isolation and working in a collaborative team creates a sense of responsibility to other members. Academic science faculty members are increasingly collaborating with their colleagues as research is becoming complex requiring the use of wide range of skills and knowledge (Katz and Martin, 1997; Melin, 2000). When faculty members collaborate on research, they provide knowledge, skills, and expertise to their collaborators and in turn receive recognition and credibility (Rijnsoever et al, 2008). From this perspective, collaboration enhances research visibility and recognition. The existence of a large number of collaborators increases the possibility that the faculty might receive a higher level of recognition and rewards. Faculty members within science are satisfied to the extent that their expectations for recognition and rewards are met or fulfilled (August and Waltman, 2004; Katz and Martin, 1997; Hermanowicz, 2003).

Gitlin and colleagues (1994) applied social exchange theory to understand collaboration. The basic assumption of social exchange theory is that individuals offer to provide their knowledge, skills, and expertise and in return receive certain benefits (Emerson, 1976; Monge and Contractor, 2003). There is inherent similarity between the process of social exchange and research collaboration as both assert the importance of interdependence. Bozeman and Gaughan (2011) found that faculty perceive greater levels of recognition as a result of collaboration with a large number of collaborators. Bozeman and Gaughan (2011) further discuss that having a large number of collaborators instills a sense of self-worth in faculty, and they perceive being appreciated and valued. Specifically, faculty interprets research visibility and recognition from their collaborators not only as fulfillment of their expectations, but also as confirmation of the validity of their work and affirmation of self-worth (Pearson and Seiler, 1983).

One of the recent studies by Leahy (2007) found that visibility within academic community is a positive contributor of rewards among academics in the fields of sociology and linguistics. Specifically, Leahy (20007) emphasizes that the process of reward attainment in academia depends on faculty members's visibility within the broader academic community. Visibility in academia is obtained when more people know faculty member's name and are aware of his or her scholarly contribution. Professional relationships therefore represent the potential for rewards and visibility within academia, and consequently satisfaction. Resources received from ones connections such as nominations for awards, and introductions to other potential scholars help increases ones visibility in academia (Bozeman and Dietz, 2001; Bozeman and Corley, 2004; Stephen, 1996; Leahy, 2007; Amick, 1974). Etzkowitz and colleagues (2000) discuss that connections to senior faculty members may help validate faculty member's credential and increases visibility as seniors have the greatest access to information, and are often associated with multiple research teams, science communities, departments, and universities, and are more likely to spot opportunities and connect juniors to those opportunities. Collaboration with a greater number of seniors may serve to validate an individual's credentials (Cross and Cummings, 2004; Cross, Borgatti and Parker, 2001). Validation results in greater self-esteem and confidence in ones abilities (Parker and Asher, 1993) and may lead to greater satisfaction.

2.3.3. Other determinants of satisfaction within academia

Faculty work in an increasingly demanding environment in which there are heightened expectations to obtain research funding, perform high quality research and teaching, and engage in service activity. Increased demands for performance have raised questions about how these pressures affect faculty satisfaction. Previous studies have found that faculty satisfaction is predicted by perceptions about the quality of work life. For example, Jonhsrud and Rosser (2002) and Rosser (2004, 2005) found that positive perceptions about aspects of work life such as adequate professional development, and administrative and technical support, contribute to satisfaction of faculty members. In addition to positive perceptions of work life contributing to satisfaction levels, previous research has found that when academics perceive autonomy in pursuing what and how they do research, and what theory and methods they want to use in their research, they report a higher level of satisfaction (Olsen and co-authors, 1995).

Demographic determinants such as gender, race, and ethnicity are among the most researched with respect to satisfaction (Mottaz, 1986; Mason, 1995). Empirical evidence indicates that men are more satisfied with salary and benefits compared to women (Hagedorn, 1996; Blackburn and Lawrence, 1995). Female faculty members report having access to fewer resources (Astin, 1991; Johnsrud and Wunsch, 1991; Olsen and Sorcinelli, 1992; Park, 2000; Parson et al., 1991; Sandler and Hall, 1986), and report receiving less support and approval from senior colleagues (Astin, 1991; Boice, 1993; Fox, 1991; Johnsrud and Wunsch, 1991; Olsen et al., 1995; Olsen and Sorcinelli, 1992; Parson et al., 1991). Female and minority faculty are especially vulnerable to being assigned to time consuming service tasks and responsibilities which makes them less satisfied (Wyche and Graves, 1992). Females are less satisfied with advising and course load as well as with rewards and benefits compared to their male counterparts (Hagedorn, 1996). However, the evidence of female faculty being less satisfied is mixed. For example, Olsen, Maple, and Stage (1995) found that female faculty appears to share the values of research scholarship and publications, just as men. Specifically, female faculty fully subscribe to the professional goals and values of a research institution and derive satisfaction from a research career (Olsen Maple, and Stage, 1995).

2.3.4. Dimensions of satisfaction in academia

A number of researchers have argued that work satisfaction is a multidimensional concept (Rosser, 2004; Olsen 1993). Several dimensions of satisfaction has been studied over the past decades such as salary satisfaction, organizational satisfaction, satisfaction with advising and course load, satisfaction with benefits and security (Smart, 1990; Rosser, 2004, 2005;). An important dimension of satisfaction among scientists concerns how well the scientist perceives that they are valued by their department and institution. Perception of being valued can take a number of forms such as receiving rewards, receiving adequate salary, as well as perceiving an adequate and equitable allocation of such resources as research support, clerical and graduate student support, technology (Johnsrud and Des Jarlais, 1994; Hagedorn, 1996). Less than half of faculty members in a national study indicated that they were satisfied with their rewards, salary, and other benefits (Magner, 1999). Research shows that academic work is increasingly become more stressful. Faculty members are expected to get research funding, perform administrative duties and so on. Based on a survey of academic employees in UK universities, Kinman and colleagues (2008) found that when academics perceive an imbalance between the amount of effort they invest in their work and the rewards they receive, they are most likely to report a lower level of satisfaction with rewards (Kinman et al, 2008; Siegrist, 2001). Other research has found that adequate rewards and professional recognition is positively related to well-being of academics (Winter and Sarros, 2002). Rewards continue to be an important issue for faculty members. Rewards convey a sense of professional accomplishment, and a lower receipt of rewards continues to be the primary reason why academic faculty leaves their institution (Matier, 1990).

Another dimension of satisfaction concerns the extent to which faculty perceive their institution and department is well recognized and carries a positive reputation within the academic community (August and Waltman, 2004). Prior work by Hagedorn (1996) found that a positive image of a scientist's university or college leads to higher levels of satisfaction and reduced stress. An actor's behavior is affected by what they believe others infer about their department and institution (Dutton et al, 1994). When actors perceive their colleagues view their department and institution in a positive light, they are likely to be satisfied with reputation of their department and institution. This prior literature supports the conclusion that faculty satisfaction with the reputation of their academic institution represents an important dimension of faculty satisfaction.

2.3.5. Gaps in the theoretical frameworks used to explain work satisfaction in academia

Some of the most common theoretical models or frameworks used to predict satisfaction are Herzberg's motivator-hygiene model and Linda Hagedorn's mediators and triggers model. Herzberg's motivator hygiene framework is often used to explain the relationship between professional lives and satisfaction of academic faculty members. Motivators are referred as intrinsic factors or perceptions individual hold regarding their work and professional environment. Motivators include achievement, recognition, work itself, responsibility, advancement, and growth. Hygienes are referred to as extrinsic factors. Hygienes are related to the work context such as salary, organizational policies and so on. Herzberg (1959) argued that motivators work to increase satisfaction, while hygienes decrease dissatisfaction. Herzberg further argued that the causes of satisfaction, and dissatisfaction were distinct, and hence labeled the theory as two factors or motivator-hygiene theory of satisfaction.

Linda Hagedorn's mediator trigger model is a modified version of motivator-hygiene framework. Hagedorn's mediators comprise motivators, hygienes, environmental conditions, and demographics. Environmental conditions, encompasses working conditions including the social and working relationships established with administrators (bosses), colleagues (coworkers), and students (subordinates). Hagedorn's model was validated using the 1993 National Study of Postsecondary Faculty (NSOPF 1993), a large nationally representative database compiled by the National Center for Education Statistics (1993). The most highly predictive mediators were the work itself, salary, relationships with administration, student quality, relationships with colleagues, and institutional climate and culture.

Some researchers have adopted a need based framework of the process by which satisfaction is determined. This stream of researchers has studied satisfaction as "need fulfillment" i.e. individuals are satisfied to the extent that their needs are met or fulfilled (Judge and co-authors, 1995) and has applied Maslow's needs hierarchy to explain satisfaction. Within the academic context, (Pearson and Seiler, 1983) have applied Maslow's need hierarchy to explain satisfaction, and intention to leave academia. Pearson and Seiler (1983) have identified faculty members in universities as that class of individuals whose "higher order needs" such as rewards, and recognition dominate in comparison to other needs. However, previous researchers acknowledge that these earlier frameworks used to predict satisfaction are in need of rejuvenation and modification. For example, although Hagedorn's mediators comprise of environmental factors such as relationship with co-workers, it does not explicitly includes the structure of relationships, as well as the strength of interactions with co-workers. As a result, this study provides a platform to examine the effects of structure of professional relationships on satisfaction in academia.

One of the first studies on the impact of interpersonal relationships on satisfaction was conducted by researchers working within the human relations tradition. In addition to the human relations tradition, several researchers have situated interpersonal relationships within the social network theoretical tradition (Coleman, 1988; Burt, 1992). Within academia science, Bozeman and colleagues (2001) conceptualized networks as the cooperative glue that binds scientists together in knowledge exchange. Crane (1969), and Price and Beaver (1966) discuss the presence of informal interaction between academic scientists working within a research area. The concept of network and its linkage to satisfaction is discussed in the following section.

2. 4. Network and Satisfaction

The original impetus for studying the impact of social relations on satisfaction was the interest of researchers within the disciplines of organizational behavior, and industrial psychology, working particularly within the human relations tradition (Vasu et al, 1998; Agneesens and Wittek, 2008). One of the important studies that are mainly characterized as the beginning of the human relations tradition was a series of experiments at Hawthorne electric plants. These studies found that individual productivity was not affected by physical factors (light, humidity, fatigue) but by interpersonal relationships at the work place (Vasu et al, 1998). As a result, any discussion of the effects of interpersonal relations and satisfaction deserves a mention of the Hawthorne experiments and the human relations tradition.

Ever since the human relations school, the interest in understanding the impact of social relations on individual outcomes is increasing among scholars within organizational studies, sociology, psychology, among others. Social relations are generally captured under the umbrella term social capital. The origin of the notion of social capital is the idea that non-monetary forms of capital (social relationships) can be sources of advantage for individuals (Lin, 1998; Burt, 1992). For example, some individuals are more successful than others because they are connected to certain others, are involved in exchange with certain others, hold a certain position within the structure of these exchanges. These exchange relations are an advantage for the individual. This advantage is social capital. In other words, social capital creates advantage for individuals such that they are more successful than others. The connections between individuals and their contacts comprise a network.

Social network theoretical perspective puts forth the idea that individual's network structure provides them access to valuable resources, which helps them attain rewards, recognition, and consequently satisfaction. Thus, rewards and recognition mediate the relationship between networks and satisfaction. In other words, networks indirectly affect satisfaction through the fulfillment of rewards and recognition. However, networks may also affect satisfaction directly by creating perceptions about oneself and about the work situation (Ibarra and Andrews, 1993). For example, individuals who are located in less advantageous network structures may not have a favorable perception of themselves, and their work situation is less advantageous, and hence they may report a lower level of satisfaction. A less structurally advantageous structure may mean that the individual is involved in exchanges with a certain other who is relatively more powerful i.e has connections to most of individual's contacts. Presence of a structurally powerful contact may lead to negative perceptions of ones work situation. Alternatively, individuals occupying structurally advantageous locations positively evaluate their work, and report a higher level of satisfaction (Rice and Mitchell, 1973; Roberts and O'Reilly, 1976; Dean and Brass, 1985).

. As discussed in the above paragraph, networks affect satisfaction by providing access to valued resources (Agneessens and Wittek, 2008). Hence depending on the individual's position in the network, strength of ties, superiority of ties, and kind of resources received from network ties, some individuals are better able to achieve higher level of rewards and recognition, and thereby increase their levels of satisfaction (Hurlbert, 1991; Agneessens and Wittek, 2008). For example, Haley Lock (2007) found that strong network ties enhance levels of satisfaction with promotions and advancement opportunities. Flap and Volker (2001) found that dense network enhance satisfaction with social aspects of the job. However, the above cited empirical studies do not use social mechanisms to explain the relationship between networks and satisfaction. Recent advances in the social network theoretical perspective provide opportunities to understand different properties of network and their effects on satisfaction.

2.4.1. Four network properties

Within the social capital research tradition, a network may be defined as the overall pattern of ties linking a defined set of actors. Each actor is described on the basis of their ties to other actors in the network. The focal actor is referred to as the ego, and those he or she is tied to are called the alters. Prior research discusses four logically distinct properties of networks: 1) network structure, 2) characteristic of ties (strength, duration, closeness), and 3) status of alters, and 4) resource received from alters. Prior research has focused mostly on the first conceptualization i.e. network structure (pattern of connection between the alters) and its role in achieving satisfaction (Flap and Volker, 2001). However, prior research also suggests that structure alone does not capture the effect that networks have on satisfaction (Cross and Cummings, 2004). Other network properties such as strength of ties, status of alters, and resources received from alters, in addition to structure, may also matter for satisfaction. In the following paragraphs, four network properties-- structure, tie characteristics, alter status, and resources received, are introduced and discussed.

a) Network structure--Constraint

Network theorists such as Coleman (1988), Krackhardt (1992) discuss about network structures in which most of ego's contacts are connected to each other. Such a highly connected or dense network promotes a normative environment where the ego is more likely to cooperate with others in the network. In other words, a normative environment promotes cooperation and trust between actors. Dense networks have been found to lead to overall well-being (Liem and Liem, 1978). Flap and Volker (2001) found that when ego's contacts are connected to each other, the ego is satisfied with social aspect of work, such as relationships with colleagues. In other words, dense networks enhance satisfaction with relationship with colleagues. The presence of known third parties in a dense network serves as an incentive for cooperative behavior, and acts as a deterrent to opportunistic behaviors. Specifically, in a dense network, failure to cooperate may damage ego's reputation and his or her ability to form new ties. Ego has less freedom or less autonomy to pursue his interests in such a highly connected environment. In other words, in a dense network, ego is constrained. Alternatively, when none of ego's contacts are connected, they cannot constrain ego's opportunities as the only linkage among alters is through the ego. Ego may be more constrained if most of his or her contacts are connected to one single alter. This structurally advantageous or hierarchical alter may pose constraint for the ego such that ego may not be able to access and control resources. Egos' located in constrained networks may report a lower level of satisfaction as a result of their inability to access and control resources. (Gargiulo and Benassi, 2000). Flap and Volker (2001) found that when ego's contacts are not connected to each other, the ego is satisfied with aspects such as career opportunities, promotions and so on. Ego is also constrained when he or she is connected to fewer ties (Burt, 1998). Specifically, fewer network ties may mean limited resources for the ego.

Fig 1. A network high in constraint

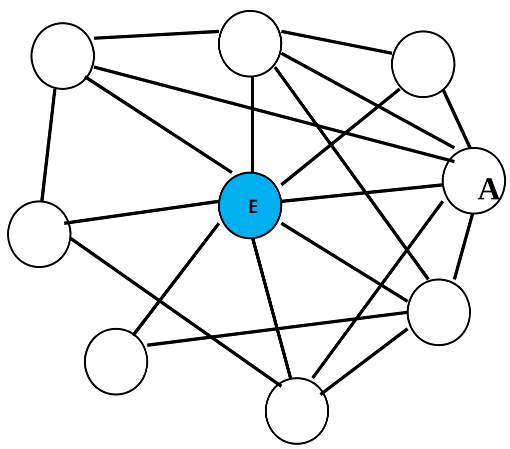


Fig 2. A network low in constraint

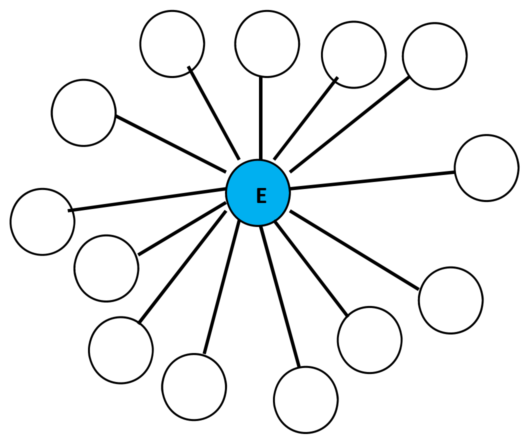


Fig 2 is an example of a network low in constraint. This network has a greater number of alters compared to fig 1. Also none of the ego's alters are connected to one another (low density) and, hence, the alters cannot constrain ego's opportunities as the only linkage among alters is through the ego. On the other hand, in Figure 1, there are fewer alters, most of them are connected to one another. Figure 1 also provides a visual of the concept of hierarchy, which is defined as the dependency of the ego on a single alter (Hanneman, 2005). In Figure 1, most of ego's connections are connected to a single alter (A). Because of this structure, the ego might find it difficult to distance himself or herself from this highly connected alter or find it critical to engage with this hierarchical alter as all of ego's connections are also connected to A. As a result, it can be said that A imposes considerable constraint on the ego.

b) Tie characteristics—Strong ties

The second network property of interest in this study is the characteristic of ties. Ties or dyadic relationship between the ego and the alter can be strong or weak. Strong ties are intimate, frequent and promote reciprocity, trust, and commitment (Granovetter, 1972; Uzzi, 1996; Krackhardt and Stern, 1988). Haley Lock (2007) found that strong co-worker ties lead to greater levels of satisfaction with promotions in a public agency. In a study among MBA students on the relationship between networks and satisfaction, Baldwin and colleagues (1997) argued that strong ties affect satisfaction by enabling access to critical resources such as information. Strong ties require a greater investment in terms of time and energy and hence are costly to maintain compared to weak ties. Strong ties link actors of similar attributes. Information shared with strong ties are therefore essentially similar. Weak ties other hand are infrequently maintained, non-intimate (Granovetter, 1972). Weak ties link dissimilar actors, and presumably, then, weak ties provide new and unique information and perspectives (Granovetter, 1973). Lin (1998) showed that tie strength was negatively related to the occupational prestige of the alter contacted (that is, weak ties reach higher-status alters) and that the alter's occupational prestige was in turn positively related to the prestige of the job secured by ego (Lin et al.,1981; De Graaf & Flap, 1988; Marsden & Hurlbert, 1988).

c) Status of alters—higher status alters

The third network property discussed is status of alters. Status stratification is common in networks. Alters may be of higher status than the ego with respect to expertise, skills, seniority, and prestige and so on (Agneessens and Wittek, 2012). Lin (1981) suggests that alters who are of a higher status have desirable resources, and ties to such a higher status alter can improve job rewards for the ego. Specifically, Lin (1999) offers four explanations as to how higher status alters may produce outcomes for the ego. First, higher status alters can provide information and other resources such as career support resources and advice to the actor. Second, higher status alters may exert influence on the departments and institutions that play a critical role in making decisions about rewarding the actor, and third, higher status alters may be conceived as credentials of the actor. Finally, higher status alters are expected to reinforce ego's identity and recognition. Others scholars have also found that higher status alters are valuable because these alters provide experience, novel information, and legitimacy (Brass, 1984; Cross, Rice, and Parker, 2001).

d) Resources received from alters

The fourth network property of interest in this study is resource received from alters. According to Lin's social resource theory, alters who provide resources to the ego are considered relevant social resource when considering ego's pursuit of career goals. Previous research discusses that resources received from alters is related to career success of egos' because of two reasons. First, resources received enhance ego's performance and his or her ability to achieve recognition and rewards, and hence higher levels of satisfaction (Seibert et al, 2001). Higgins (2000) found that the greater the resources from network ties, higher the levels of work satisfaction. Hurlbert (1991) also found that resources provided by alters leads to higher levels of job satisfaction. Second, resources received from alters provide legitimacy to the ego such that he or she may perceive to be socially valued. These perceptions increase feelings of control and competence at work, and of psychological empowerment (Spreitzer, 1996; Gist and Mitchell, 1996). Egos' who perceive that they are psychologically empowered tend to be more satisfied with their careers (Spreitzer, 1996).

The above four network properties focus on different aspects of networks. Network constraint focuses on the pattern of connection between alters. Strong ties vs. weak ties perspective focus on the nature of ties, Status of alters refers to the superiority of alters in terms of expertise, seniority, and skills. Resource received from alters focuses on the desirable resources that the ego receives from alters which helps the ego achieve career goals. Lin's social resource theory argues that higher status alters, and resources received from alters are relevant social resources which helps the ego attain a higher level of success. An integration of these four network properties is possible because they focus on different aspects.

Several scholars argue that network based explanations of satisfaction are incomplete (Agneessens and Wittek, 2008). They suggested that models that link network structure and outcomes need a better foundation which will not only provide detailed analyses of network properties but also specify underlying processes or social mechanisms that link network properties and satisfaction. As a result, in this dissertation, social mechanisms approach is utilized to understand the relationships between networks, rewards and recognition, and consequently satisfaction. The first step to linking networks, rewards, and recognition, and satisfaction is to first understand what is meant by social mechanisms and examine the different types of social mechanisms.

2.5. Social mechanism linking networks and outcomes

The term social mechanism is applied to a diverse range of processes that explain an observed relationship (Hedström and Swedberg, 1996). Anderson et al (2006) discuss social mechanisms as theoretical cogs on wheels that explain why two variables covary. A focus on social mechanisms enables thinking beyond individual variables and their specific relationships to thinking about the causal process in its entirety. Social mechanisms add precision to theories; provide deeper, direct and fine grained explanations of the relationship between cause and effect. A social mechanism based view to theory building focuses on understanding why and how observable relationships exist (Weber, 2006). Hedstrom and Swedberg (1996) illustrate an example on how social mechanism focuses on understanding why and how observable relationships exist. Hedstrom and Swedberg (1996) illustrate a situation where the social mechanism or underlying process of belief formation influences an individual's choice of action. Specifically, the situation is about an individual who in an unfamiliar town enters an unknown restaurant. Whether or not the individual decides to take a meal there depends on the underlying process of belief formation. The numbers of people present at the restaurant signals to the individual about the value and quality of the restaurant. In other words, the number of people present in the restaurant leads to the formation of certain beliefs in the minds of the individual about the quality of the restaurant. Presence of lots of people in the restaurant signals to the individual or makes him or her believe that the restaurant is of good quality and positively affects his or her decision to take a meal at the restaurant. The number of people who perform a certain act signals others about the likely value or necessity of the act, and this signal influences individual's choice of action.

Mechanisms are not like deterministic laws in which certain inputs lead to certain outputs; rather mechanisms help us address the probabilistic nature of social phenomena. Mechanisms are also not like pure descriptions which provide an account of events as they happened one after the other. Rather mechanisms are located somewhere on a middle ground between universal laws and descriptions (Hedström and Swedberg, 1996). Mechanisms are often unobserved or are only observed in their effects (Mayntz, 2004). For example, several empirical studies reveal that individuals located in constrained networks are less likely to do well in their careers than individuals in unconstrained networks. Why is this so? What is it about the nature of disadvantage that individuals in constrained networks face that leads to their failure? We may posit the existence of an unobservable social mechanism to explain the relationship between constrained networks and lower levels of individual success. In structurally constrained networks, the relatively powerful alter may not confer legitimacy to the individual. The fact that the individual is aware that he or she does not enjoy social approval or acceptance may affect his or her ability to be successful. In other words, the awareness of being illegitimate may discourage the individual to pursue career goals. Here, the unobservable social mechanism of legitimacy explains the relationship between constrained networks and individual's success in his or her career

To explain how social mechanisms lead to better and deeper theorizing, suppose we have strong reasons to believe that individuals embedded within constrained network structures *(X1),* individuals with greater proportion of strong ties *(X2)*, and individuals who are connected to superior alters *(X3),* and individuals who are receive greater amount of resources from their alters *(X4)* are satisfied *(Y)*. Yet a larger question remains. Why and how do network factors such as constraint, strong ties, status of alters, and resources received from alters lead to greater levels of satisfaction? Figure 3 suggests some inner workings, or social mechanisms that link constrained network structure, strong ties, superior alters, and resources received and satisfaction. These social mechanisms provide theoretical explanations that link structure, ties, and resources to satisfaction. While the mechanisms are not necessarily observable, they are the connective logic that causally link independent and dependent variables that are visible.

This research discusses six social mechanisms that link network constraint, strength of ties, status of alters, and resources received from alters to rewards and recognition, and consequently satisfaction. All of these social mechanisms fall under the rubric of interpersonal influence mechanisms. Specifically, interpersonal influence mechanisms are those social mechanisms that explain satisfaction as a result of "what the social structure can do for the ego". Interpersonal influence mechanisms perceive ego as a mere "recipient of the social structure" (Agneessens, 2008).

It is important to note here that the six social mechanisms do not link all the four network properties and satisfaction. In other words, while one or few social mechanism may be relevant for linking one network property and satisfaction, these social mechanisms may not be relevant for linking another network property and satisfaction. For example, the social mechanism of reciprocity links strong ties and satisfaction. However, reciprocity may not be relevant for linking higher status alters and satisfaction; some other social mechanisms may be relevant for linking higher status alters and satisfaction. The implication of this logic is that social mechanisms are not all purpose laws that can be applied always and everywhere.

The first social mechanism, ***social control,*** refers to attempts on the part of ego's contacts to force and control ego's behavior (Thoits, 2011). Certain network structures enhance the functioning of social control. For example, in a structurally constrained network is one where most of ego's contacts know each other, and where one particular alter is structurally more powerful, the ego may be socially controlled such that opportunities, rewards, and recognition, may be withheld from him or her. Egos' without rewards and recognition may report a lower level of satisfaction.

The second social mechanism, ***legitimacy*** refers to social acceptance and appropriateness (Burt, 1998). When one says that the ego and his or her actions are legitimate, one is saying that the social system approves and accepts the ego. In structurally constrained networks, relatively advantaged alter may confer legitimacy to the ego or use his or her relative power advantage to withhold legitimacy from the ego. It may be difficult for the less legitimate egos' to attain rewards and recognition, and consequently satisfaction. Connections to superior alters may help the ego gain legitimacy (Cross and Cummings, 2004). In other words, superior alters may help sponsoring the ego as a legitimate actor. Legitimacy is likely to increase rewards and recognition, and consequently satisfaction.

The third social mechanism, ***access*** refers to gain in resources, opportunities, and reputational advantages that an ego may acquire through connections to alter who occupy structurally advantageous positions (Lin, 1999). Alternatively, structurally advantageous alters may also exercise their power by withholding access to rewards, recognition from the ego. Lower access to rewards and recognition may lead to lower levels of satisfaction. An ego may also access resources by means of connection to alters who are superior to the ego in terms of expertise, skills, and seniority. Access to resources by means of connections to superior alters may result in higher rewards and recognition, and consequently satisfaction.

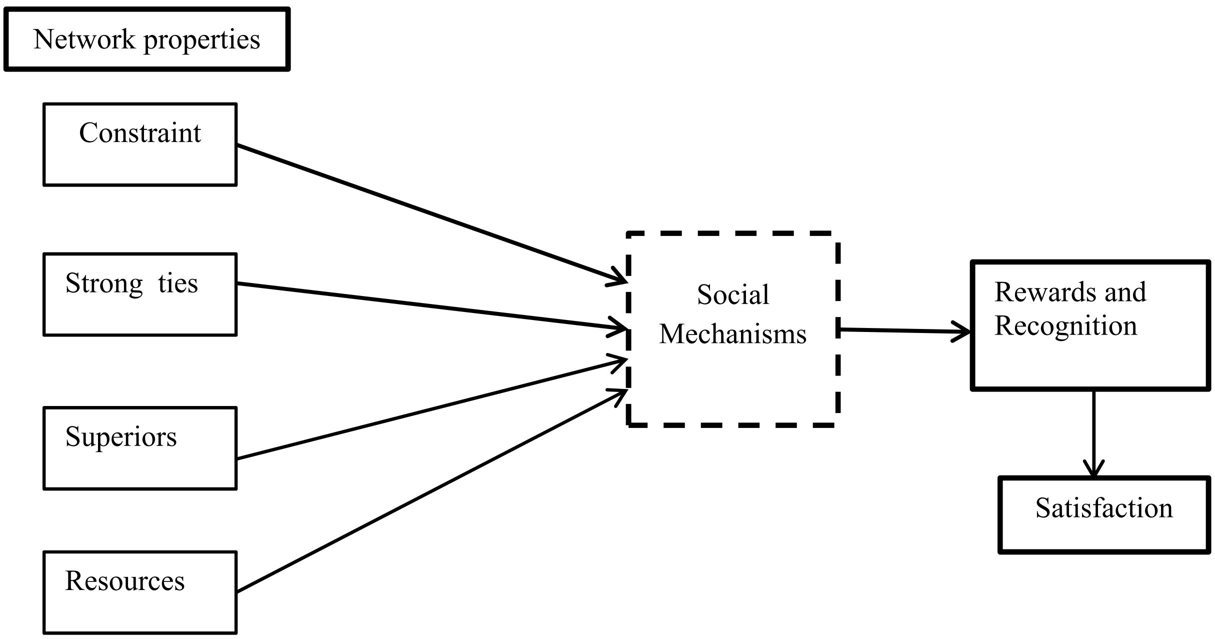
The fourth social mechanism, ***reciprocity*** is the giving and receiving of resources and support. Strong ties are important for the initial giving of resources and support, and sets the giving and receiving process in motion (Plickert et al, 2007). In other words, strong ties may initially provide resources the ego. The ego, then obliges to respond positively setting the reciprocity cycle in motion. Reciprocity is the mechanism that enables ego to achieve rewards and recognition, and consequently satisfaction. For example, the ego may provide knowledge to the alter, who in turn provides recognition to the ego.

The fifth mechanism, ***sense of personal control*** is experienced when individuals successfully complete a task. Perceptions in ones sense of control sustains confidence to cope in the face of new challenges (Thoits, 2011). Connections to superior alters may evoke perceptions of a lack of personal control, and perceptions of being incompetent. Such perceptions may lower ego's ability to achieve rewards and recognition, and consequently satisfaction.

The last and sixth social mechanism, ***validation and resource efficiency*** is the assurance that ego's idea and plans are reasonable and appropriate. Validation yields efficiency benefits to the ego such that once the research ideas are validated, the ego need not collect and analyze more information (Cross et al, 2001). Connection to superior alters may yield validation and resource efficiency benefits to the ego such that egos' may be able to increase performance, attain rewards and recognition, and consequently satisfaction.

In the above paragraphs, the six social mechanisms were introduced and how they link network properties and satisfaction was briefly discussed. Each of the social mechanism is discussed in detail in the next chapter where the role of social mechanism in how they link a particular network property to satisfaction is illustrated in the form of hypothesized relationships.

Fig 3. Relationship between networks, social mechanisms, rewards, and recognition, and consequently satisfaction



2.6. Summary of the chapter

This chapter provides a literature review of the effects of networks on satisfaction generally and in the academic context. Satisfaction is defined as a positive mental state resulting from the fulfillment of rewards and recognition. The importance of satisfaction as a concept emerges from its association with low turnover and overall well-being. Just as in the general context, satisfaction is a widely researched topic within academia. The reason for the popularity of the concept of satisfaction in academia is not so different from that of the general organizational context. Specifically, high levels of satisfaction lead to low turnover in academia. Several determinants such as perceptions of work life, collegial relationships, gender, rank, disciplinary context affect satisfaction within the academic context. Satisfaction is mostly defined as a multidimensional concept which encompasses rewards and recognition, work load, advising and so on within academia. Faculty members are motivated to attain rewards and recognition. Faculty form collaborative relationships with colleagues—gives their knowledge and in return receives recognition and rewards. Satisfaction results from the fulfillment of recognition and rewards. The process of collaboration closely resembles social exchange. Previous theoretical frameworks used to explain satisfaction in academia include collegial relationships, however little attention has been given to understanding the effects of the structure of relationships on satisfaction. This research provides an opportunity to examine the effects of networks on satisfaction of faculty members in academic science and engineering.

The origin of the research on interpersonal relations and work satisfaction was undertaken by researchers working within the human relations tradition. Within this tradition, satisfaction resulted from collegial relationships at work. Interpersonal relations are generally captured under the umbrella term social networks. A key contribution of social networks theoretical perspective is the general idea that individual's network structure provides them access to valuable resources, which help them attain rewards, recognition, and consequently satisfaction. Four network properties are included in this study: network constraint, strength of ties, status of alters, and resources received from alters. Networks lead to rewards, and recognition, and consequently satisfaction through several underlying processes or social mechanisms.

3. MODEL DEVELOPMENT AND HYPOTHESES

3.1. Introduction

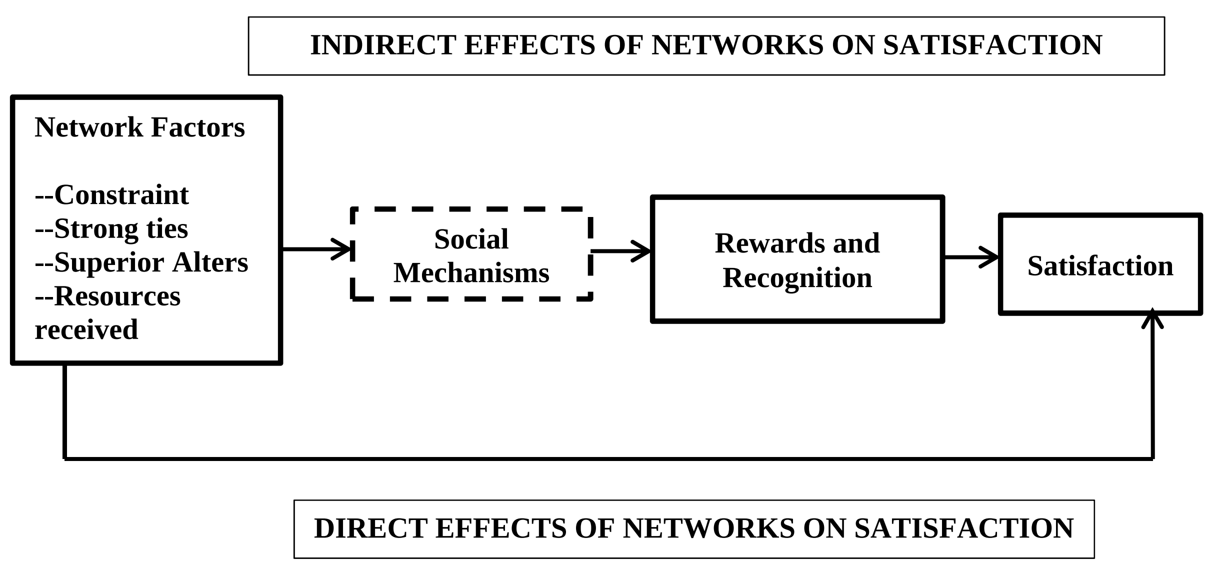
The previous chapter discussed four network properties namely network constraint, strength of ties, superior alters, and resource received from alters. In addition to the four network properties, social mechanisms or underlying processes that link networks and satisfaction were also introduced in the last chapter. In this chapter, an integrated theoretical framework is developed to explain satisfaction among academic faculty in science and engineering fields. This integrated theoretical framework includes social network theoretical perspective, social mechanism, expectancy theory of motivation, and social exchange theory. Social network theoretical perspective explains that certain individuals achieve greater levels of rewards and recognition because of the structure of their networks. Social exchange theory posits that actors engaged in social exchange are mutually dependent on each other and provide each other with rewards, recognition, and other valued goods that they cannot achieve on their own. Collaboration among academic scientists resembles social exchange such that when they collaborate, they provide their knowledge to their collaborators, and in return receive knowledge, and recognition from them. Expectancy theory of motivation explains satisfaction as a result of fulfillment of rewards and recognition. This integrated theoretical framework explains that collaborative networks via underlying social mechanisms lead to satisfaction through the fulfillment of rewards and recognition.

This chapter is divided into seven sections. The first section provides a detailed discussion of network theoretical perspective, expectancy theory of motivation, and social exchange theory in order to explain the reader with the concepts of these theories and how they relate to rewards, recognition, and satisfaction. The second section discusses the social mechanisms that link networks, rewards and recognition, and consequently satisfaction. In the third section, the direction of the effects between each network property and satisfaction is predicted and stated in the form of testable hypotheses. Each network property is linked to satisfaction through one or more social mechanisms or processes that are clarified in the hypotheses. Theoretical and empirical justification for each hypothesis is provided drawing from networks, social mechanisms, expectancy theory of motivation, and social exchange theory. The fourth section provides propositions on the relationship between the four network properties themselves. The fifth section discusses the role of non-network factors on satisfaction. In the sixth section, a model specifying the relationship between collaborative networks and satisfaction is presented in a diagrammatic form. Explanation of this diagram is also presented in this section. The last or seventh section provides the summary of the chapter.

3.2. Integrated theoretical framework comprising networks, social mechanisms, social exchange theory, and expectancy theory of motivation

The theoretical framework presented in this chapter is an integration of network theoretical perspective, social mechanisms, expectancy theory of motivation, and social exchange theory. This integrated theoretical framework explains that networks factors such as constraint, strong ties, superior alters, and resources received from alters via certain social mechanisms or underlying processes lead to outcomes such as rewards and recognition. Satisfaction results when expectations regarding rewards and recognition are met. Specifically, networks via social mechanisms indirectly affect satisfaction through the fulfillment of rewards and recognition. However, networks may also affect satisfaction directly through positive evaluations of oneself and the work environment generally. Certain network structures allow greater control of resources, and thus lead to favorable perceptions about themselves, including higher levels of work satisfaction (Rice and Mitchell, 1973; Roberts and O'Reilly, 1979; Dean and Brass, 1985).

Fig 4. Linking networks, social mechanisms, rewards, recognition, and satisfaction: An integrated theoretical model



3.2.1. Network theoretical perspective

Some individuals do better in the sense of receiving higher rewards and recognition for their efforts. Some individuals quickly become prominent. Some individuals lead important projects. The social network explanation of why some individuals perform better or are highly rewarded and recognized than others is because they are connected to certain others, are dependent on exchange with certain others, and hold a certain position within the structure of these exchanges (Burt, 1992).

Each individual has a network: contacts that the individual collaborates with, contacts that the individual is friends with and so on. In network terminology, the individual here is referred to as the ego, and the contacts are the alters. The structure of ego's network-- how the alters are connected to each other, the relationship that ego has with his or her alters, status of the alters, and resources that the ego receives from the alters determine ego's performance, levels of recognition, perceptions about ones skills and abilities, work satisfaction and so on. Certain network structures allow greater control of resources. Specifically, individuals located in structurally advantageous positions enjoy a wide array of opportunities and thus hold a favorable view of themselves, and the work situation. A large number of studies suggest that structurally advantageous locations are associated with positive evaluations of job and workplace features, including work satisfaction (Ibarra and Andrews, 1993; Roberts and O'Reilly, 1979; Dean and Brass, 1985).

Network theorists such as Coleman (1988) and Krackhardt (1992) find that high interconnectivity among individuals in the network creates a normative environment in which obligations and promises are kept, and the uncertainty of exchange between actors is reduced. In a highly connected or dense network, the presence of common third parties serves as an incentive to display a cooperative image, and acts as a deterrent to opportunistic behavior. Specifically, in the presence of third parties, the ego is more likely to conform to norms of reciprocity as failure to do so may result in strong sanctions and damage to ego's reputation. Such an all connected network structure amplifies the pressure to reciprocate. Egos' are often overburdened by demands posed by the alters (Portes and Sensenbrenner, 1993). In such an environment, ego loses freedom to pursue what he or she wants (Gargiulo and Benassi, 2000). The constraining effect of such a network is even more when a single alter has ties with most of ego's contacts.

This relatively powerful alter may constrain opportunities for the ego such that ego may not be able to attain higher level of recognition and rewards, and consequently may be less satisfied. In network terminology, such a network structure is referred to as network constraint. Specific hypothesis related to network constraint and satisfaction is developed later in this chapter.

In addition to patterns of connection between alters, network theoretical perspective also includes aspect such as characteristics of ties or dyadic relationship between the ego and alter (Cross and Cummings, 2004). Network ties can be either strong or weak. Strong ties are characterized by higher frequency of interaction, longer duration, and greater closeness. Weak ties on the other hand are less intimate and infrequent. Strong ties are more motivated to provide resources (Krackhardt, 1992). Strong ties are likely to link similar actors, and therefore provide redundant information to the ego. Weak ties, on the other hand are likely to link dissimilar actors and therefore provide diverse information to the ego (Granovetter, 1973). Specifically, weak ties provide the opportunity for the ego to come in contact with people of different social groups or statuses.

Network theorists such as Lin (1981) suggest that 1) higher status alters, and 2) alters who provide resources to the ego can be relevant social resource when considering an ego's pursuit of career goals. Higher status alters have desirable resources, and access to resourceful others, and that ties to such people can improve job rewards (Lin, 1999). Connections to higher status alters provides experience, novel information, validation of ideas and plans, and legitimacy to the ego (Brass, 1984; Cross, Rice, and Parker, 2001). Resources received from alters is related to career success of individuals because of two reasons. First, resources received from alters enhance an ego's performance and ability to achieve recognition and rewards (Seibert et al, 2001). Second, resources received provide legitimacy to the individual such that he or she may perceive to be socially valued. These perceptions increase feelings of control and competence at work, and of psychological empowerment (Spreitzer, 1996; Gist and Mitchell, 1996). Individuals who perceive that they are psychologically empowered tend to be more satisfied with their careers (Spreitzer, 1996).

3. 2. 3. Social exchange theory: A network perspective

Social exchange is a joint activity of two actors in which each actor has something that the other values. The basic tenet of social exchange theory is that actors are mutually dependent on each other to accomplish goals they cannot achieve on their own. The goal of the actors engaged in exchange is to generate valued goods or rewards that provide each other with more benefits than otherwise (Molm, 1991). According to Cropanzano and Mitchell (2005), social exchange involves interdependent interactions that generate expectations, obligations, and trust.

Social exchange occurs within structures of mutual dependence. Social exchange theorists and network theorists both view social structure as a configuration of exchange relations involving the exchange of valued items (material, informational, symbolic) (Cook and Whitmeyer, 1992; Molm, 1991, 2000; Lawler and Thye, 2006). Hence, it is appropriate to analyze exchange relations as social network relations and apply network concepts to understand the effects of exchange relations on outcomes such as rewards and recognition. Certain exchange relations may provide more valued outcomes or rewards to one another than others. For example, in close exchange relations, actors' expectation of reciprocity spurs the initial giving of valued resources. This initial giving obligates the other actor to respond positively setting the giving and receiving cycle or reciprocity cycle in motion (Plickert et al, 2007). Reciprocity in exchange fosters a variety of positive perceptions about ones capacity of achieving valued outcomes. For example, actors engaged in reciprocal exchange may perceive that they can successfully do things together that generate rewards for both. These perceptions of self-efficacy reflect a sense of shared responsibility. These perceptions also generate positive evaluations of oneself and about ones work including work satisfaction (Molm, 1994; Lawler and Thye, 1999).

As discussed before, actors in the exchange relation provide valued benefits to one another which make them mutually dependent on each other. An actor's (A) dependence on the other actor (B) varies inversely with the availability of benefits from alternate sources. These alternate sources are other actors. If there are many alternate sources for actor A, then actor A is less dependent on actor B. The less dependent and relatively powerful actor A has a power advantage over B. Thus, exchange relation between A and B is marked by power imbalance. Power advantage gives actor A an advantage in the exchange such that A may use strategies to withhold rewards from actor B. Such exchange relations are less likely to be reciprocal (Molm, 1991, 1994; Emerson, 1976).

Within the context of academic science, research collaboration between academic scientists resembles social exchange such that scientists are motivated to collaborate because collaboration results in rewards and recognition, which scientist's value. Specifically, when scientists collaborate, they exchange knowledge for rewards, and recognition. Not all exchange relations may not result in the same levels of rewards and recognition. Depending on the network structure within which the collaborative exchange takes place, strength of the collaborative exchange relation, status of the collaborator, and resources received from the collaborators, certain collaborative exchanges may result in greater levels of rewards and recognition compared to others. For example, collaborative exchange with a relatively powerful collaborator may result in lower rewards and recognition as the powerful collaborator may withhold rewards from the ego scientist.

3.2.4. Expectancy theory of motivation

Expectancy theory of motivation was introduced in the field of industrial-organizational psychology by Vroom (1964), and was integrated into a model of job satisfaction by Lawler and Porter (1967). According to this theory, an individual is motivated to engage in an activity because of the expectation that the activity will result in higher rewards (Wabba and House, 1974; Locke and Latham, 1990; Mitchell, 1974). When expectations of rewards and recognition are met, individuals report a higher level of satisfaction (Porter and Lawler, 1968; Fried and Ferris, 1987). Specifically, the theory is based on two concepts (1) expectations or subjective probability that effort or activity will result in rewards, (2) fulfillment of rewards leads to satisfaction.

Individuals do not exist in a social vacuum. Their expectations about rewards may depend on their location in the social structure. Specifically, when an individual collaborates with another individual, his or her expectation that collaborative activity will result in rewards may depend on the (1) structure within which the collaborative exchange takes place, (2) the strength of the collaborative relationship, (3) status of the collaborator, and (4) resources received from the collaborators. For example, collaborative exchange with a structurally powerful collaborator may not create expectations about achieving rewards as the structurally powerful collaborator may be controlling, and coercive in the collaborative interaction with the individual. On the other hand, collaborative exchange with a close collaborator may create expectations about achieving higher level of rewards because close collaborators are more likely to reciprocate. Collaborative exchange with a higher status collaborator may create expectations about achieving a higher level of rewards because higher status collaborators may have higher access to resources and opportunities, and may connect the individual to those opportunities When the individual receives resources from his or her collaborators, it may create expectations of receiving higher level of rewards as receipt of resources from others enhances a sense of psychological empowerment (Gist and Mitchell, 1992).

Within the context of academic science, Whitley (2003) found that academic scientists are motivated to build their reputation and earn recognition within the broader academic community. They are motivated to engage in activities that can enhance their recognition (Latour and Woolgar, 1986). One such activity is collaboration. Specifically, academics are motivated to collaborate as they expect collaboration to result in greater levels of knowledge gain, and greater recognition, and rewards (Katz and Martin, 1997; Rijnsoever, 2008). Recognition is a socially validated testimony that the academic scientist has fulfilled the goal of science which is to extend certified knowledge (Merton, 1957; Hagstrom, 1965). Collaboration also helps acquire funding which in turn forms the basis of new research activity (Rijnsoever, 2008). Thus, collaboration helps sustain and expand a scientist's position within academia. Satisfaction among academics results when their rewards and recognition expectations are met. Given the arguments above that academic faculty collaborate as they expect collaboration to result in rewards and recognition, and that fulfillment of rewards and recognition results in satisfaction, it seems appropriate to apply expectancy theory of motivation in academic science settings to explain the role of collaborative relations on satisfaction. The underlying processes or social mechanisms through which collaborative networks lead to rewards and recognition, and consequently satisfaction are discussed in the following section

3.3. Social mechanisms

Little attention has been paid to understand the underlying processes through which collaborative networks influence scientist's rewards and recognition, and consequently their satisfaction. This study elaborates the role of several unobserved social mechanisms that explain the processes through which collaborative networks lead to rewards and recognition, and thereby affect satisfaction among academic faculty in science and engineering fields. A large and growing body of literature on mechanisms and the role of mechanism based explanations or mechanism based approaches to theory building have emerged in the social sciences. A common theme in much of this literature is that identifying social mechanism that link cause and effect is crucial for the development of deeper and fine grained explanation of social phenomena.

Astbury and Leeuw (2010) discuss that social mechanism have three characteristics: 1) mechanisms are unobservable or hidden, 2) mechanisms are sensitive to variations in context, 3) mechanisms generate outcomes. A first key characteristic of social mechanism is that they are unobservable. A favorite metaphor used to demonstrate that mechanisms are unobservable is the clock. It is not possible to understand how a clock works by examining the surface—the numbers on its face and the movement of its hands. We may have to prise the clock open, and go beneath the surface and delve into the inner workings of the clock (Astbury and Leeuw, 2010). The second key characteristic of social mechanisms is that they are sensitive to variations in context. Certain contexts may be more conducive for the activation of social mechanisms. For example, in context A, social mechanism, M1 may be activated because conditions are conducive. However, context B, the conditions may not be conducive to activate mechanism M1. Within the realm of this study, presence of strong ties may provide conditions conducive to activate the social mechanism of reciprocity. While another context such as presence of higher status alters may not provide the conditions conducive to activate reciprocity; some other social mechanism may be activated in such contexts. The implication of this logic is that social mechanisms are not universal laws that can be applied always and everywhere. The third key characteristic of social mechanisms is that they generate outcomes. The logic here is that outcomes are not only caused by observable inputs but also due to unobservable processes, or social mechanisms, and the interaction between mechanisms and contexts. Within this study, satisfaction among academic scientists consists of not only the variables that we observe such as network properties, but also the underlying processes or social mechanisms and the interaction between networks and mechanisms.

The current study discusses the role of six unobservable social mechanisms which explain how collaborative networks lead to satisfaction. The six social mechanisms are social control, legitimacy, access, reciprocity, sense of personal control or mastery, and validation and resource efficiency. In the following paragraphs, I discuss the six mechanisms, and then discuss hypotheses linking social mechanism, collaborative exchange, rewards and recognition and satisfaction.

Social Mechanism One: Social Control

Social control refers to explicit attempts on the part of alters to monitor, persuade, or pressure the ego to change their attitude or behavior (Thoits, 2011). There are two potential ways through which social control functions. First, social control may lead to resentment, frustration and distress as the ego perceives alters in the network to be overly intrusive or dominating (Thoits, 2011; Lewis and Rook, 1999). Specifically, the ego in a constrained network structure may perceive the persuasive and controlling behavior of the hierarchical alter as intrusive and dominating, and may report lower levels of satisfaction. Second, social control exerted by alters can improve mental and physical health of the ego. For instance, if the ego experiences psychological distress alters in a constrained network are likely to observe this behavioral change and attempt to intervene. To the extent that the effort of alters in intervening are successful, ego's well-being can be enhanced. Certain network structures may enhance the functioning of social control. For instance, a structurally constrained network may make the behavior of ego more visible, and the alters may intervene by persuading the ego to change his or her behavior.

Social Mechanism Two: Legitimacy

Legitimacy is a generalized perception that an individual and his or her actions are desirable, proper, and appropriate within some socially constructed system of norms, values, and beliefs (Suchman, 1995). Legitimacy is socially constructed in that it reflects congruence between behavior of the legitimated individual and the shared beliefs of some social group. In short, when one says that a certain individual and his or her behavior is legitimate, one asserts that the social system as a whole approves, and accepts that individual (Suchman, 1995; Burt, 1998). Within the network literature, Burt (1998) found that structurally advantageous contacts within a social network provide legitimacy to the ego. Alternatively, alters in structurally advantageous positions may use their resource and power advantage to withhold legitimacy from the ego. Alters who are superior to the ego in terms of status, skills, and expertise may also provide legitimacy as they are likely to have a greater breadth of information and experience. Connection to these superior alters legitimates the ego and provides them with confidence in his or her abilities (Cross and Cummings, 2004).

Social Mechanism Three: Access

Access refers to gain in resources, opportunities, and reputational advantages (Burt, 1992). An ego may acquire access to resources through connections to alters who occupy strategic locations in the structure as well as from alters who are superior to the ego in terms of rank, status, skills, abilities, and expertise. Prior research has found that contacts occupying structurally advantageous locations within networks may provide help to the ego by means of invitations, favorable referrals, locating research opportunities, and sponsorship (Burt, 1998; Etzkowitz et al, 2000). Alters in such strategic locations hold valued resources, and may exercise greater power to impact decisions that are made by institution and department about rewarding the ego. Alternatively, alters occupying structurally advantageous positions may exercise their power by withholding access to rewards, recognition, and reputation from the ego. Connection to superior alters in terms of status, skills and expertise may help ego secure valued resources. According to Lin (1999, 2001), presence of superior alters in networks provides reassurance to the department and institution that the ego can provide added value, which may result in higher rewards – larger salaries, more graduate student support, better clerical support for the ego.

Social Mechanism Four: Reciprocity

"Doing for others if they have done for you" is referred to as reciprocity (Plickert et al, 2007). The principle cause of reciprocity is giving resources. Several factors are important for the initial giving of resources. For example, tie characteristics such as frequency and duration of relationship, and close friendships are factors that may initiate the giving of resources. This initial giving obligates the ego to respond positively, setting the social exchange process in motion with the norm of reciprocity coming into picture thereafter (Plickert et al, 2007). Reciprocity is the key mechanism through which actors mobilize resources that helps them achieve individual goals. Egos' may exchange the same resource with their alters—knowledge for knowledge or may exchange different resources—knowledge for knowledge as well as knowledge for recognition.

Egos' may not expect on all of their alters to provide resources. Based on the strength of the relationship, some alters may provide more resources to the ego compared to others. Also, egos' may exchange different resources based on the type of relationship. For example, resource exchanged with close friends may be different from resources exchanged with less close alters. Within the context of this study, ego scientists exchange knowledge for knowledge as well as knowledge for recognition with their collaborators. Scientist may expect more knowledge and recognition from their exchange with close collaborative ties.

<u>Social Mechanism Five: Sense of Control or mastery</u>

A sense of control is experienced when individuals successfully complete a task. In other words, the more frequently one completes a task successfully, the more strongly one is likely to believe that he or she has control or mastery over one's work (Thoits, 2011). Sense of personal control or mastery has been examined in the literature on coping with stress, where it is positively related to better physical and mental health. Perceptions of a sense of control sustain confidence in one's ability to cope in the face of new challenges and thereby are associated with lower anxiety (Turner and Roszell 1994; Kessler, Turner, and House 1988). According to Agneessens and Wittek (2011), connections to higher status may signal ego's lack of personal control. Specifically, egos' with a large number of higher status collaborators may perceive themselves to be less competent.

<u>Social Mechanism Six: Validation and resource efficiency</u>

Assurance that one's ideas or plans are appropriate and reasonable is referred to as social validation (Cross, 2000). Previous research has found that sometimes individuals turn to others not to seek additional information but because of the validation their plans and solutions receive (Cross and Sproull, 2001). Assurance that the research idea or plan is reasonable or appropriate by superior alters provides a type of professional validation (Cross, Borgatti, and Parker, 2001). Cross and Sproull (2001) shows that validation by alters superior in ability can also yield efficiency benefits to the ego, once ego's ideas are validated, the ego need not collect and analyze more information. In other words, validation of ego's research ideas or plans decreases the time required to discuss that idea or plan as well. Reduced discussion time and reduced effort required to analyze more information leads to increase in efficiency, and may lead to greater levels of performance. Enhanced performance may lead to higher rewards and recognition, and consequently greater satisfaction.

The above discussion on social mechanisms reveals that they are sensitive to network context. Social mechanisms get activated in different ways depending on the network context. For example, strong ties activate the social mechanism of reciprocity, and superior alters activate the social mechanisms of validation and legitimacy. Social mechanisms provide the linkage between networks, rewards, and recognition, and consequently satisfaction. In the following section, explanation is provided for each network property—network constraint, strong ties, superior alters, and resources received for a particular kind of network namely collaborative network leads to satisfaction among academic scientists and engineers. Collaborative networks are composed of relations through which scientists share resources such as knowledge, technical information, and guidance on publications and grants (Katz and Martin, 1997). In other words, collaborative networks are means for obtaining resources that facilitate recognition, and rewards.

3.4. Linking collaboration networks, social mechanisms, rewards, and recognition, and satisfaction

Research collaboration is increasingly becoming complex requiring the use of a wide range of skills and knowledge. No single scientist possesses all the knowledge and skills required to conduct scientific research. When scientists collaborate, there is a greater possibility that collaborators will possess a necessary range of skills and knowledge to conduct scientific research. During the course of collaboration, a scientist not only gains knowledge and expertise but may also gain novel insights, enhance their social and management skills needed to work as a collaborative team, gain visibility and recognition, and enhance their individual productivity (Katz and Martin, 1997; Melin, 2000; Lee and Bozeman, 2005).

Hagstrom (1965) refers to collaboration as gift exchange, i.e. when scientists collaborate; they give away their knowledge for free, and in turn receive new knowledge, visibility and recognition, awards, and research funding. Latour and Woolgar (1979) discuss that scientist’s value recognition and rewards, and hence are motivated to collaborate because they expect collaboration to result in higher recognition. Greater recognition and rewards from collaborative exchanges may fulfill scientist’s expectation for recognition and rewards, leading to higher levels of satisfaction. Collaborative exchange within certain network structures may be better for developing competencies and expertise necessary to attain recognition and rewards compared to others. In other words, certain kinds of collaborative network structures may result in greater fulfillment of recognition and rewards compared to others.

3.4.1. Linking collaboration network constraint, social mechanisms, rewards, and recognition, and satisfaction

Structures of network relationships determine access to and control of valued resources. Actors who are strategically positioned within networks have greater control over relevant resources and enjoy a broad array of benefits and opportunities not available to those actors who occupy less strategic positions (Burt, 1982; Brass, 1992; Ibarra, 1993). From this perspective, a structurally less advantageous network structure is one in which the ego has few alters to seek resources from. Fewer numbers of collaborators may mean less recognition, and rewards, from collaborative exchanges. Lower recognition, rewards, and reputation may not fulfill scientist's expectation with rewards and recognition, resulting in lower levels of satisfaction. Alternatively, with a large number of collaborative network ties, the scientist may receive a higher level of recognition and rewards.

An ego is structurally less advantaged or constrained if most of alters are connected to one another as the ego cannot control opportunities available to him or her because the alters have enough alternatives other than the ego (Hanneman, 2005; Marin and Wellman, 2009). Specifically, ego is highly constrained in dense networks wherein most alters are connected to each other. Dense structure allows monitoring of each other's action, actors may not engage in norm defying behaviors because such behavior would put an actor's reputation at stake (Gargiulo and Benassi, 2000). Thus, a dense network structure constrains ego's individuality by enforcing group norms. Ego loses freedom to pursue what he or she wants in a dense network structure (Gargiulo and Benassi, 2000).

Further, a constrained network invokes pressure to reciprocate (Lawler, 2001; Coleman, 1988). This pressure to reciprocate and the fear of damaged reputation due to failure to reciprocate may lock ego and alter into exchanges even when they do not view any rewards, or recognition accruing from the exchange (Leifer, 1988). Exchanges without any value or benefits may lead to lower level of satisfaction. Another negative aspect of dense networks is that the strong bonds of familiarity and cooperation can act as a filter or a "cognitive lock in" that isolates the ego and alters from the outer world, limiting them to interaction with redundant contacts, which might not result in fulfillment of recognition and rewards (Gargiulo and Benassi, 1997).

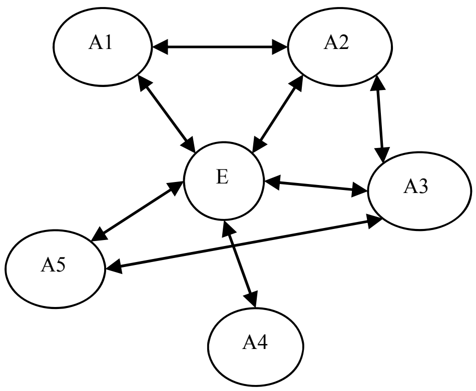


Fig 5. Low in Density

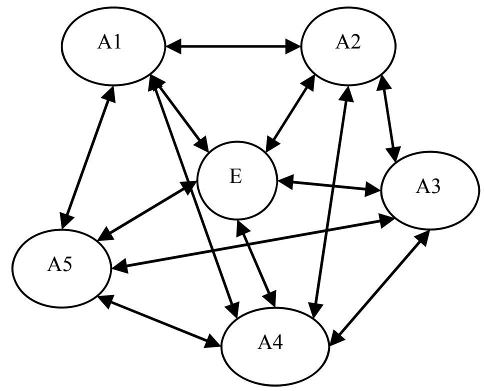


Fig 6. High in Density

As networks comprise both actors and relationships between them, it is likely that both are hierarchically arranged. Specifically, the relationships among actors may be hierarchically structured such that some actors have access to more relationships or are more centrally connected than others. From this perspective, a hierarchical network structure is one in which a single alter in the ego's network has proportionally more ties; this alter has access to more relationships as compared to others in the network. In other words, the structurally hierarchical alter is more central than others in the network. Because, the central alter has more relationships from which to draw resources, he or she is less dependent on any other individual actor, and relatively more powerful compared to the ego. Previous research suggests that ego's dependence on a particular alter varies (1) with the value of the benefit that particular alter can provide, and (2) inversely with the availability of the benefit to the ego from alternative sources. These alternative sources are the other alters to whom the ego is connected. If ego connects to only one alter (A), ego is completely dependent on A (Molm, 1991; Emerson, 1976). If ego (E) connects with three alters (A1, A2, A3), and none of them are connected to each other, then structural hierarchy is zero, since neither of ego's contacts are structurally powerful relative to the ego. If most of the alters in ego's network are connected to a particular alter then that alter is structurally more powerful in relation to ego. For instance, if E is connected to three alters (A1, A2, and A3), all of them are connected to A2, then A2 imposes considerable constraint on E, and E is situated in a structurally hierarchical network. These two scenarios are depicted in figures 4 and 5.

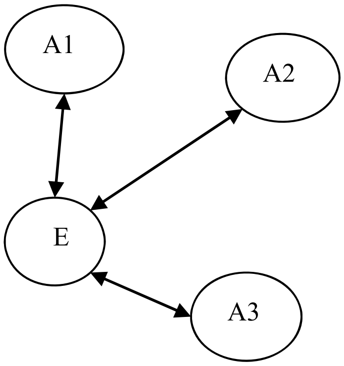


Figure 7. No Structural Hierarchy

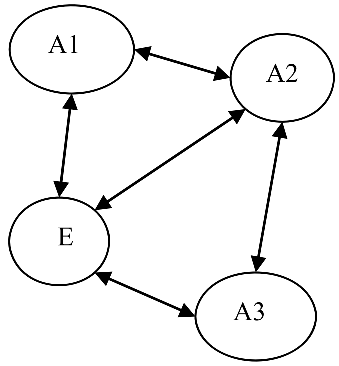


Figure 8. High Structural Hierarchy

Actors located in structurally powerful locations are able to appraise the social system more clearly (Freeman and Romney, 1987). Because of the increased ability to appraise the structure, the structurally powerful alter makes informed decision on what resource to draw from whom. Also, egos' who occupy structurally powerful locations are able to hear information about possible opportunities and threats faster than individuals located on the margins of the network (Brass, 1984; Ibarra and Andrews, 1993). Alternatively, egos' that are structurally disadvantaged or located in hierarchical networks are not able to know about opportunities. From organizational and management literature, we know that structural advantage in communication networks leads to greater level of satisfaction with work context among MBA students in a large mid-western university (Baldwin et al (1997). In sum, a structurally powerful alter has a greater access to and control of resources, and may report a higher level of satisfaction (Brass, 1984; Seibert et al, 2001; Ibarra and Andrews, 1993; West et al, 1999).

Structural power affects an alter's capacity to influence ego's outcomes in an exchange relationship. Specifically, in collaborative exchanges that are characterized by power imbalance, the relatively powerful alter can be *controlling, persuasive, even coercive* in interactions with the ego. Otherwise stated, in a constrained network, the relatively powerful alter can use the mechanism of social control to monitor the ego. Additionally, alters in relatively powerful structural positions may also use behavioral strategies to enhance their benefits. For example, the structurally powerful alter may use his or her power to withhold rewards or professional recognition from the ego or may not help the ego gain *legitimacy*, thereby leaving the ego discontent (Gargiulo and Benassi, 2000). Previous literature by Burt (1992) found that actors with constrained networks suffer slower promotion rates.

Within the context of academic science, collaborative interaction with the structurally powerful collaborator may be unfair and unequal as this collaborator controls more resources and has a power advantage over the ego scientist. The structurally powerful collaborator may use his or her power to withhold informational resources, rewards, or professional recognition from the ego scientist or may not help the ego scientist gain influence and legitimacy. It is also reasonable to expect that an ego scientist who is dependent on a structurally powerful collaborator may have lower access to resources and hence may be less likely to accumulate knowledge to able be able to publish and receive grants. Within academic science settings, Melin (2000) found from his interviews that collaborative context where one scientist made all the decisions was perceived to be less rewarding. As a result, one expects that reward expectations of an ego scientist located in a structurally hierarchical or a constrained collaborative network may be unfulfilled, and hence he or she may report lower levels of satisfaction. Alternatively, lower constraint in collaborative networks may lead to better access to information about new research ideas, new developments in the field, new opportunities of funding, and about details of surviving in the competitive research environment. Greater *access* to information may reduce uncertainty and ambiguity and the ego scientist would be more confident of a being recognized, and rewarded, and hence report greater levels of satisfaction. In other words, the social mechanism, access explains why less constrained or structurally advantageous actors are able to fulfill their reward expectations.

While the social mechanisms—social control, legitimacy, and access link network constraint and satisfaction indirectly through the fulfillment of rewards and recognition, some researchers have found that constrained networks may directly affect satisfaction through perceptions. For example Ibarra and Andrews (1993) discuss that actors occupying structurally advantageous locations positively evaluate their work because such locations allow for greater resource control and power over others. Other studies have also found that structurally advantageous locations within networks result in higher work satisfaction (Rice and Mitchell, 1973; Roberts and O'Reilly, 1976; Dean and Brass, 1985), perceived access to resources, and perceptions of belonging or acceptance (Coleman, Katz, and Menzel, 1966). Alternatively, actors occupying disadvantaged locations may have negative perceptions of work because of their inability to control resources. For example, in a constrained network structure, the ego may perceive that he or she is being controlled, and may form negative perceptions about their capability of receiving rewards and recognition. Specifically, in an exchange process characterized by power imbalance, the relatively less powerful actor perceives himself or herself to be socially less valued, or less legitimate, which may be associated with lower satisfaction. Previous research has found that negative perceptions formed as a result of interacting with relatively powerful alters are critical factors in determining their ego's satisfaction (Settoon et al, 1996).

Another theoretical argument explaining why actors occupying structurally disadvantageous locations have a negative view of their work is because the disadvantaged actors are more likely to come in contact with similar others who also have a negative perceptions of work and other dimensions related to work such as rewards, recognition and so on. This perspective is consistent with the body of research that indicates that people who are similar develop shared perceptions (Wellman, 1983; Dean and Brass, 1985; Ibarra and Andrews, 1993). Going by all the arguments above, one may expect:

H1: Collaborative network constraint will be negatively related to satisfaction of academic scientists.

3.4.2. Linking strong collaborative ties, social mechanisms, rewards, and recognition, and satisfaction

Network researchers have traditionally focused on the pattern of connection among alters in the network, and paid less attention to the features of ties, or relationships, within these networks (Cross and Cummings, 2004). Nevertheless, ties or relationships also affect access to and control of resources. For example, certain kinds of ties or relationships may provide greater resources compared to others.

Previous research suggests that actors cannot expect help from all of their network ties and not all ties provide the same kind of resources (Plickert et al, 2007). Strong ties are which are characterized by higher frequency of interaction, longer duration, and greater closeness are more motivated to provide resources and help (Wellman, 1999; Krackhardt, 1992). Weak ties, on the other hand are less intimate, infrequent, and provide information from diverse sources, beyond those available within ego's immediate social circle (Granovetter , 1973). Specifically, weak ties provide the opportunity for the ego to come in contact with people of different social groups or statuses.

Exchange with strong ties garners expectations of reciprocity in which the alter obligates the ego or vice versa to return goods or services. Said in another way, the initial giving of resources creates expectations of reciprocity which obligates the ego to respond positively to the resource provided to him or her, setting the process of giving and receiving or a self-reinforcing reciprocity cycle in motion. Reciprocity is a key mechanism through which egos' mobilize resources to achieve individual outcomes. Egos' may exchange knowledge, material, or emotional resources with their alters. Alters may reciprocate with the same resource which he or she received from their strong ties or may reciprocate with a different resource.

Within the context of academic science, when the ego scientist engages in collaborative exchange with strong ties, there is greater expectation of reciprocity, and greater probability that collaborative exchange will leads to higher rewards, and consequently higher levels of satisfaction. Said in another way, scientists may be more motivated to show reciprocity to their strong collaborative ties, i.e. scientists may be more motivated to give their knowledge to strong collaborative ties. Similarly, the collaborators may be motivated to accord recognition to the scientist with the expectation that the scientist would provide resources in return ranging from new knowledge to recognition and so on. This produces a reciprocity cycle. *Reciprocity* may be viewed as a mechanism through which scientists gain rewards and recognition within the scientific community. Hence, with a greater number of reciprocal collaborative ties, scientists may achieve a higher level of satisfaction through fulfillment of objective rewards and recognition. The concept of reciprocal exchange has been used by previous scholars to explain positive attitudes about work, greater levels of work satisfaction, organizational commitment, and intentions to stay in the organization (Liden et al, 2000; Chiaburu and Harrison, 2008).

In addition to strong reciprocal collaborative ties indirectly leading to satisfaction through the mediating influence of objective rewards and recognition, strong ties also directly lead to satisfaction by creating perceptions of self-efficacy. Previous research has discussed that in reciprocal exchange relationships, giving and receiving resources from exchange partners enhance feelings of self-worth (Rook, 1987). These positive perceptions may lead to satisfaction. Previous research has found that actors are more satisfied with their work when there is a congenial environment created by large number of reciprocal strong ties (Gottlieb, 1985).

Alternatively, connections to a large number of strong ties may lead to lower levels of rewards and recognition, and hence lower levels of satisfaction. Specifically, McFadyen and colleagues (2009) argue that in close relationships, the exchange partners are likely to be very similar in terms of knowledge, skills, methods used and so on. Although, the similarity in knowledge and skills may result in greater efficiency in collaborative exchange, it may limit the exposure of the ego to diverse actors and diverse ideas and perspectives essential to new knowledge creation and greater recognition. Collaborative exchange with redundant strong ties lock ego and alter into exchanges which accrue fewer rewards and recognition (Leifer, 1988). Weak ties, on the other hand, connect to distant part of the social system opening up opportunities for the ego to get connected to diverse actors in the disparate parts of the social system, which may result in greater recognition from the broader community, thereby leading to higher levels of satisfaction. Capturing both sets of argument, and all else equal, one expects:

H2a: Scientists with a greater number of strong collaborative ties will report higher levels of satisfaction

H2b: Scientists with a greater number of strong collaborative ties will report lower levels of satisfaction

3.4.3. Linking superior collaborators, social mechanisms, rewards, and recognition, and satisfaction

Network theorists such as Lin (1981, 1999) suggest that alters superior to the ego in terms of status are relevant social resources which help the ego in his or her pursuit of individual goals. According to Cross and Cummings (2004), superior ties are likely to provide validation of ego's plan or idea. *Validation* from superior alters enhances self-esteem, and also yields efficiency benefits to the individuals such that once the ideas are validated, the ego need not collect and analyze more information (Parker and Asher, 1993). Efficiency helps increase performance, and one's ability to achieve rewards and recognition. In addition to validation, superior alters can provide *access* to resources (Lin, 1999), and *legitimacy* to the ego (Brass, 1984; Cross, Rice, and Parker, 2001). Validation, access, and legitimacy accruing from collaborative exchange with superior alters is likely to increase rewards, and recognition, and thereby satisfaction (Cross et al, 2001; Parker and Asher, 1993). The social mechanisms of validation, access, and legitimacy link superior collaborators to rewards, and recognition, and consequently satisfaction. Within academic science context, Etzkowitz et al (2000) suggests that senior scientists typically have the greatest access to information and opportunities. Their networks are wide in reach and they are likely associated with cross cutting teams, departments, and universities. These senior scientists connect juniors to new opportunities. Collaborative exchange with senior scientists may thus increase the chances that scientist's expectations of rewards and recognition are fulfilled.

Although validation by superior ties increases confidence and self-esteem, and hence positive evaluations of one's capabilities in achieving rewards and recognition (Parker and Asher, 1993; Sparrowe and Liden, 2006), some researchers argue that connections to superior ties may signal ego's incompetence or a *lack of sense of control* over ones work (Goffman, 1971). This social status perspective posits that the primary objective is to maintain social status within networks. Connections to superior ties lowers the status of the ego and enhances the status of the superior alter (Blau, 1956). A loss of status may result may lead to negative perceptions about oneself. In collaborative exchanges with superior alters, the ego often perceives being, incompetent, or unable to reciprocate in return for the assistance received (Buunk et al, 1993). Perceptions of being incompetent or a lack of sense of control over ones work may result in unfulfilled reward expectations. Liden and colleagues (2000) have found that a lack of sense of control leads to lower level of satisfaction among employees in a university. Alternatively, Olsen, Maple, and Stage (1995) found that a sense of control over ones career positively impacts satisfaction among faculty members in research I institutions.

Another argument on why superior ties may not lead to satisfaction comes from the integration of the homophily and weak ties theoretical perspectives. According to the homophily literature, we know that frequent interactions and closeness develop between actors of similar attributes and status (Lin, 1999). The conceptual integration of homophily and strong ties perspective leads to an expectation that superior ties are weak ties as superior ties are more likely to be of dissimilar status. Weak ties are less likely to provide validation and legitimacy (Lin, 1999). With more superior ties in one's network, the ego is less likely to receive greater rewards, recognition, and hence is more likely to express lower levels of satisfaction. Capturing both sets of arguments, one may expect:

H3a: Scientists with greater number of superior alters in their collaborative network will report higher levels of satisfaction

H3b: Scientists with greater number of superior alters in their collaborative network will report lower levels of satisfaction

3.4.4. Linking resources received, social mechanisms, rewards, and recognition, and satisfaction

Based on a survey of lawyers from 12 law firms in the state of New York, Higgins (2001) found that lawyers who received greater resources from their networks reported a higher level of work satisfaction. In the organizational literature, Cross et al (2001) suggests that greater receipt of resources from networks helps the ego by providing solutions to career related problems or reformulating the problems by focusing on important dimensions. Receiving greater amounts of resources from ones network signals that the ego has significant potential to be successful (Seibert et al, 2000).

Within the context of academic science, introductions to collaborators in other universities provide opportunities for productive interactions (Bozeman and Dietz, 2001; Bozeman and Corley, 2004) and greater recognition (Stephen, 1996). Nominations for awards and invitations can heighten scientist's visibility in the academic arena (Amick, 1974). Introductions and nominations help earn greater *legitimacy* (Burt, 1998), which may lead to greater satisfaction (Podolny and Baron, 1997). Greater visibility derived from receipt of resources from collaborators fulfill expectations of rewards and recognition, and hence lead to greater satisfaction among scientists (Gmelch et al, 1984; 1986; August and Waltman, 2006). The social mechanism, legitimacy links resources received, rewards and recognition, and consequently satisfaction.

Greater amount of resources from network ties enhances self-esteem, and leads to positive evaluation of one's ability (House et al, 1988). When the ego is aware that he or she is receiving resources from ones network, he or she perceives being valued, and may be satisfied with his or her work situation (Higgins, 2000). Gist and Mitchell (1992) found that receipt of resources from ones networks enhances a sense of psychological empowerment, and consequently satisfaction. Hence, all else equal, one may expect:

H4: Scientists that receive more resources from their collaborative networks will report higher levels of satisfaction.

3.5. Relationship between collaborative network properties: Propositions

The four network properties namely, networks constraint, strength of ties, status of alters, and resources received from alters are all conceptually inter- related. A constrained network is high in density i.e most or all of the alters are connected to each other. Alters in a dense network are redundant in the sense that they convey similar information and resources to the ego (Seibert et al, 2001). Alters in a dense network are likely to be strongly tied to each other, and are also likely to be of the same social status (Seibert et al, 2001). An extension of this argument suggests that networks that are constrained may comprise a lower number of superior status alters as superior status alters are of dissimilar status (Lin, 1999). One may make the following proposition:

P1: Network constraint will be negatively related to the number of superior status alters

Strong ties are characterized by higher frequency of interaction, longer duration, and greater closeness. Strong ties have greater motivation to provide assistance and are more easily available (Krackhardt, 1992). Previous research has found that strong ties provide greater amount of information and career support resources (Krackhardt, 1992; Seibert et al, 2001). One may make the following proposition:

P2: The number of strong ties will be positively related to amount of resources received

Previous research suggests that close, frequent, and reciprocal interactions take place between actors of similar attributes (Lin, 1999). Since, frequent and close interactions signify strong ties, then strong ties link actors of similar attributes. Specifically, a conceptual integration of homophily and strong ties perspective results in the argument that strong ties link actors of similar status. An extension of this argument (heterophily argument) would suggest that strong ties are less likely to be superior alters as superior alters are of dissimilar status:

P3: The number of strong ties will be negatively related to the number of superior status alters

Social network theorists such as Lin (1999), and Cross and Cummings (2004) have discussed that superior alters often possess desirable resources such as prestige, power, greater breadth of information, experience, and access to others. Organizational studies have also found that superior status alters provide greater information and career support resources. Mardsen and

Hurlbert (1988) found that connections to alters who are superior in terms of skills and expertise improve job rewards for egos.

The academic science literature discusses that one of the values that scientists ascribe to is humility. The value of humility leads scientists to insist on how little they have been able to accomplish, and further leads them to acknowledge their personal limitations, and reliance on predecessors who have prepared the way for the scientists to do research and contribute to the pool of knowledge (Merton, 1957). It is likely that socially enforced value of humility encourages the scientist to collaborate with superior network ties. Collaboration with superior status alters is considered a valuable resource for problem solving and career development (Agneessens and Wittek, 2011; Cross and Parker, 2004). Etzkowitz et al (2000) has suggested that senior scientists have greater access to resources and opportunities, and are likely to spot career related opportunities and connect junior scientists to those opportunities. One expects that a greater proportion of superior advice ties may lead to a greater receipt of career development resources. Hence, one may make the following proposition:

P4: The number of superior status alters will be positively related to the amount of resources received

3.6. Non network factors

Non network control variables that are included in the study are: receipt of organizational resources, number of courses taught or co taught, and department faculty size. Faculty members that receive resources such as laboratory space, equipment and technical support, software, quality classroom facilities, administrative support for grant writing and grant management feel more appreciated and supported in the department (Rosser, 2004, 2005; Johnsrud and Des Jarlais, 1994). Alternatively, not receiving these resources can have a demoralizing effect on faculty members. Adequate resources can engender a sense of control over one's work, while a lack of adequate resources contributes to a sense of powerlessness (Spreitzer, 1996). Bilimoria and colleagues (2006) found that receipt of resources within the department contributes to satisfaction among faculty members. As, a result, this study uses receipt of organizational resources as one of the control variables.

Previous studies have shown that faculty members who spend a greater percentage of their time on teaching in research I universities have a lower level of work satisfaction (Liu, 2001). One commonly held view among faculty member in research I universities is that teaching takes away huge chunk of time away from research and scholarly activities (Rosser and Tabata, 2010). Although teaching evaluations is perceived as an important component of promotion and tenure review, it may not lead to satisfaction in research I universities (Hagedorn, 2000). Faculty members in research I universities who spend more time in teaching may be less satisfied. As a result, this study includes number of courses taught or co taught as a control variable.

Number of faculty in the department has been found to be linked with departmental prestige and reputation (Abbott, 1972; Ehrenberg and Hurst, 1996). Several studies have reported a strong positive correlation between faculty size and departmental prestige (Burris, 2004; Lindzey and Coggeshall, 1982). Greater number of faculty is a resource that facilitates the creation and maintenance of interdepartmental networks, and enhances departmental reputation (Burris, 2004). If number of faculty is positively related to departmental reputation, it is reasonable to presume that department faculty size may be positively related to satisfaction with departmental reputation. As a result, this study includes faculty size as one of the control variables as one expects faculty size to be related to satisfaction.

Several other demographic variables such as gender, rank, academic fields, and race are also included as controls in the study. Previous research suggests that women faculty tend to have lower satisfaction with pay compared to their male counterparts (Tang and Talpade, 1999; Seifert and Umbach, 2007). Olsen and colleagues (1995) found that women faculty report receiving receive lower levels of recognition and support compared to men faculty. As a result, one expects gender to be strongly related to satisfaction. Previous studies have concluded that minority faculty has a lower level of satisfaction compared to other faculty members (Antonio, Cress, and Astin, 1997; Olsen et al 1995). Hence, this study includes race as one of the control variables. Full Professors report a higher level of satisfaction compared to assistant professors (Oshagbemi, 1997). Hence, one expects that rank may be significantly related to satisfaction. Academic fields have also been found to affect satisfaction among academic faculty. Previous research has discussed that faculty members in one academic field resemble each other more closely than faculty members in other fields (Smart et al, 2000). Moreover, satisfaction is found to be significantly related to academic field (Neumann and Finaly 1991; Terpstra and Honoree 2004). In light of these findings, this study includes six fields of science and engineering: physics, chemistry, biology, earth and environmental science, electrical engineering, and computer science as control variables.

3.7. Model of collaborative network determinants of satisfaction

Fig 6 shows the linkages between collaborative networks, unobserved social mechanisms, rewards and recognition, and satisfaction. According to the model, four network properties on the left hand side, network constraint, strong ties, superior alters, and resources received from collaborators lead to rewards and recognition, and satisfaction through unobserved social mechanisms. The model explains of two routes or ways through which collaborative networks lead to satisfaction. First, collaborative networks lead to satisfaction through fulfillment of objective outcomes such as rewards and recognition. Second, collaborative networks directly lead to satisfaction based on evaluative judgment or perceptions shaped by the structural environment.

Collaborative exchanges embedded in constrained network structures lead to lower levels of objective rewards and recognition, and consequently lower level of satisfaction due to lower number of collaborative exchanges. Specifically, fewer collaborative ties may not accord enough recognition, and rewards. A constrained network is high in density which means most of the alters know each other. Collaborative exchanges with redundant alters may not provide enough recognition and consequently lead to lower levels of satisfaction. A constrained network is hierarchical. Collaborative exchange with hierarchical alter may not accrue recognition, rewards, and reputation because the hierarchical alter is *controlling* and can use his or her power advantage to withhold recognition and *legitimacy* from the alter, consequently leading to lower levels of satisfaction. Specifically, the effect of collaborative network constraint on satisfaction is mediated by rewards and recognition. The direct relationship between collaborative network constraint and satisfaction is expected to be negative based on the argument that actors in constrained networks perceive that they are being controlled, and unfairly treated. Perceptions of unfair treatment may lead to lower levels of satisfaction.

Collaborative exchanges with strong ties are likely to be *reciprocal*, resulting in greater receipt of recognition, rewards, and consequently leading to greater levels of satisfaction. Strong reciprocal ties tend to bond similar people, and these similar people are connected to one another resulting in a closed, dense network. Because, strong ties are reciprocal, the recognition may come from a limited set of redundant collaborators, resulting in a lower level of satisfaction. In summary, satisfaction (lack of satisfaction) may result from strong reciprocal collaborative exchanges mediated by objective reward and recognition. This represents the indirect effect of strong collaborative ties on satisfaction through mediation of objective rewards and recognition. Strong collaborative ties may also directly affect satisfaction due to positive perceptions, and a sense of self efficacy as a result of support from reciprocal collaborative ties.

Strong ties are conceptually related to other network properties such as career support resources received and superiority of alter. Since strong ties are more motivated to help, one expects strong collaborative ties to provide greater amounts of career support resources. Strong ties are likely to link actors of similar attributes, as a result, one expects number of strong ties in one's collaborative network to be negatively related to the number of superior alters as superior alters are of dissimilar status.

Collaborative exchanges with superior alters can lead to higher levels of rewards and recognition through the mechanisms of *access*, l*egitimacy, and validation of ideas and plans,* thereby lead to higher levels of satisfaction. Alternatively, from a social status perspective, connections to a large number of superior alters may suggest that ego scientist is incompetent or is of a lower status who is in need of rewards and recognition, thereby leading to lower level of satisfaction. The direct effect of superior collaborators on satisfaction is expected to be negative as collaborative exchanges with a superior alter may create perceptions of incompetence.

Superiority of ties is conceptually related to resources received from ties. Previous research suggests that superior scientists have greater control of professional resources and are more likely to spot opportunities and connect junior scientists to those opportunities (Eztkowitz et al, 2000). As a result, one expects that having a greater number of superior collaborators will result in greater receipt of career development resources.

Greater amounts of resources received from collaborative exchanges such as introductions and nominations may lead to greater rewards, and recognition, and thereby higher levels of satisfaction through the underlying processes of *legitimacy,* and *validation*. The direct effect of resources received from collaborators and satisfaction is expected to be positive as receipt of resources from ones networks enhances self-esteem and a sense of psychological empowerment, which ultimately leads to satisfaction.

The novelty of this model lies in its ability to test direct as well as indirect effects of collaborative networks on satisfaction. Specifically, collaborative networks indirectly affect satisfaction through rewards and recognition. Collaborative networks also directly affect satisfaction as actors form evaluative perceptions regarding their interactions with collaborators, and these perceptions are critical factors in determining their satisfaction (Settoon et al, 1996). For example, collaboration with strong ties creates perceptions of self-efficacy. In summary, indirect effects is based on the argument that fulfillment of objective rewards lead to satisfaction, and direct effects is based on perceptions of self-efficacy, and a sense of control over ones work.

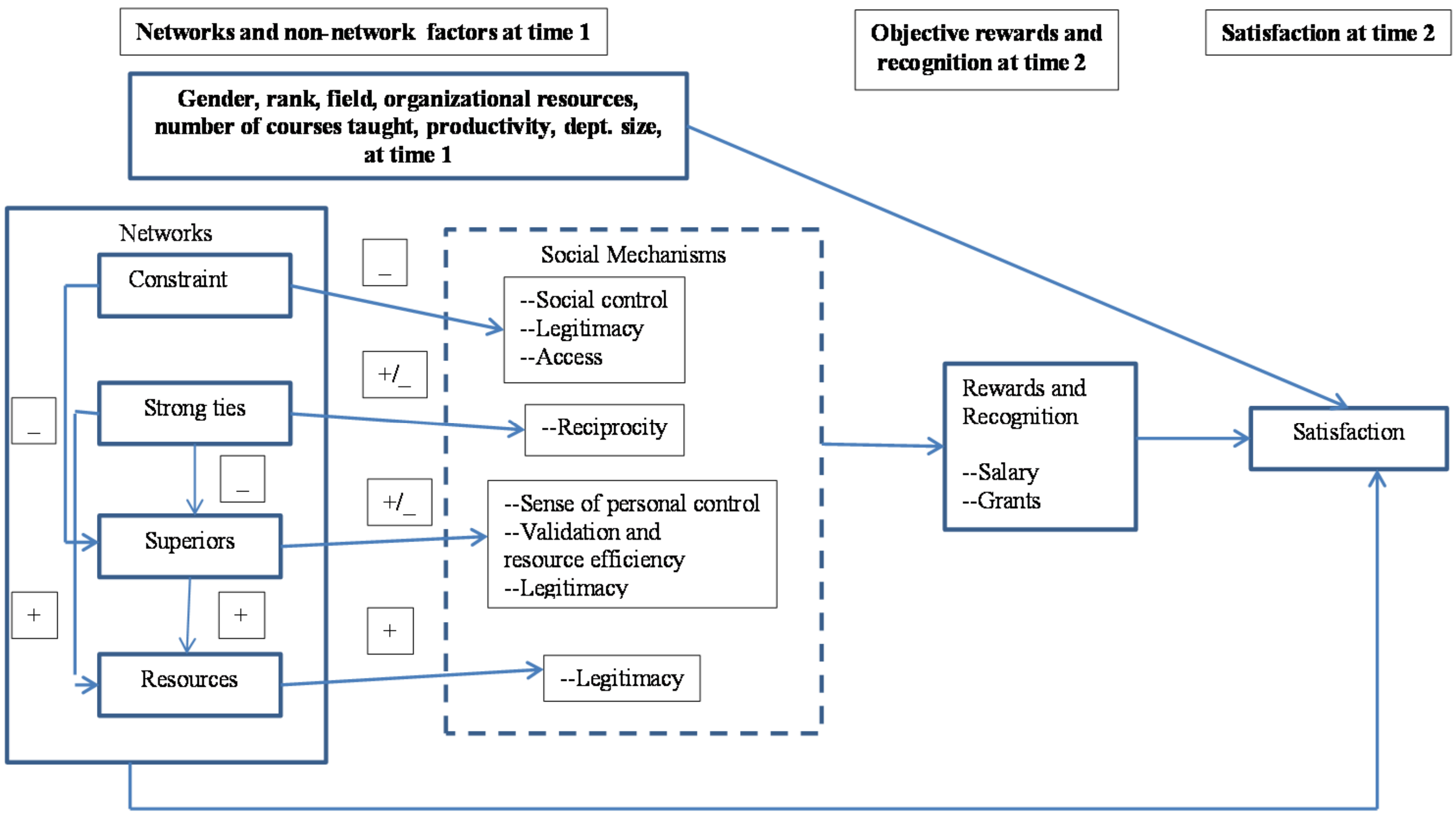
3.8. Summary of the chapter

The chapter developed a theoretical framework by integrating social network theoretical perspective, social mechanisms, social exchange theory, and expectancy theory of motivation to explain the effect of collaborative networks on satisfaction of academic scientists and engineers. The overarching social network perspective explains that some egos' are able to achieve greater levels of success as they are located in certain kind of structure, connected to certain alters, and receive resources from their network ties. Four network properties namely network constraint, strong ties, superior status of alters, and career support resources received from ties are expected to result in satisfaction through fulfillment of rewards and recognition. Several underlying processes or social mechanisms link network properties to rewards and recognition, and consequently satisfaction. Social mechanisms are hidden or unobservable and vary with network context i.e. a particular social mechanism that gets activated in a particular network context may remain dormant in other network context. For example, social mechanism of reciprocity is activated in the presence of strong ties, and the social mechanism of legitimacy is activated in the presence of superior alters.

Academic scientists are motivated to collaborate as they expect collaboration to result in recognition and rewards. Collaboration between academic scientists is conceptualized as social exchange wherein scientists exchange knowledge for recognition. Depending on the network structure within which collaborative exchange takes place, strength of the collaborative relation, status of the collaborator, and resources received from collaborators, some collaborative exchanges result in greater levels of recognition and rewards. Greater recognition results in greater levels of satisfaction in science. Collaborative exchange within constrained network structures is expected to result in lower levels of recognition, and consequently lower levels of satisfaction due to lower number of exchanges, exchanges with redundant collaborators, and due to unfair exchanges with a relatively powerful collaborator who can be *controlling*, and can use behavioral strategies such withholding rewards, recognition, and *legitimacy* from the scientist. In addition to the indirect effects of collaborative network constraint on satisfaction through the mediating role of rewards and recognition, constrained networks may affect satisfaction directly also through creation of negative perceptions. Specifically, the ego scientist may perceive being less valued and illegitimate in the presence of a structurally powerful collaborator, and hence report lower levels of satisfaction. Strong collaborative ties are expected to increase the level of recognition, and rewards, and consequently satisfaction through the mechanism of *reciprocity*. Alternatively, strong collaborative ties decrease the levels of satisfaction due to lower recognition received from similar status collaborators. Strong collaborative ties may also enhance perceptions of self-efficacy, and hence satisfaction. Collaborative exchange with superior collaborators results in greater levels of recognition, and rewards, and consequently satisfaction as superior collaborators provide *legitimacy* and *validation* of scientist's ideas. Alternatively collaborative exchange with superior collaborators may result in a lower level of satisfaction because the scientists may perceive a loss of status, and a lack of control over ones career due to collaboration with a higher status collaborator. Greater receipt of career support resources leads to greater levels of satisfaction due to *legitimacy* and *validation* benefits. Receiving resources also enhances ego's psychological empowerment, and hence satisfaction.

The four network properties—network constraint, strong ties, superior status of alters, and career support resources received from ties are conceptually related to each other. For example, a constrained collaborative network is more likely to comprise of alters of similar attributes and status, and hence less likely to comprise of superior alters as superiors are of dissimilar status. Strong collaborative ties in ones networks are expected to be positively related to career support resources received from collaborators. Strong ties are likely to bond actors of similar attributes and status. Hence, strong collaborative ties may be negatively related to the number of superior collaborators in one's collaborative network as superior collaborators are of dissimilar status. As superior collaborators have greater control over resources, the scientists may receive greater amounts of career support resources from these superior collaborators. In addition to discussing the hypothesized relationships between networks and satisfaction, and the relationships between networks themselves, this chapter also discusses the role of non-network factors such as organizational resources, perceived influence, and time devoted to teaching in satisfaction.

Fig 9. Linking collaborative networks, social mechanisms, rewards, and recognition, and satisfaction



4. DATA, MEASURES, AND METHODS

4.1. Introduction

The last chapter presented a theoretical model which integrated social network perspective, expectancy theory of motivation, and social exchange theory. This integrated model explained the role of collaborative networks on satisfaction of academic scientists, mediated by rewards and recognition. Several underlying processes or unobserved social mechanisms were shown to link collaborative networks to rewards and recognition. Fulfillment of rewards and recognition leads to higher levels of satisfaction. Specifically, networks via social mechanisms indirectly affect satisfaction through the fulfillment of rewards and recognition. Networks may also affect satisfaction directly through positive evaluations of oneself and the work environment generally (Ibarra and Andrews, 1993). In this chapter, the network constructs, recognition and rewards, the satisfaction construct are described. A detailed description of data, measures, and methods is provided. Subsequent chapters 5 and 6 will present findings and conclusion respectively.

4.2. Sample and Data Collection Procedure

The data for this study comes from a two phase national survey of academic scientists and engineers in Research I universities in the United States. The survey collected data at two points in time on demographics, individual background, career timeframe and experiences, rewards, and recognition, productivity, grants received, perceived influence in the department, resources received from the department, satisfaction, and network data. The primary motivation of this two phase national study is to understand how and why networks matter for career outcomes of academic faculty is six fields of science and engineering. The study applies knowledge from social network theory to explore the dynamics of networks in which academic scientists enter and participate. The study is unique in that it gathers data on network content and knowledge exchange at a national scale. The survey uses an ego-centric network design to explore the respondents' relationships with the individuals in the respondents collaborative and advice networks, not the global network of which individuals are members (Wasserman and Faust 1994). Through the use of detailed survey questions respondents describe their networks for selected activities and their relations with network members (Burt and Minor 1983; Straits

2000; Marin 2004). As a result, both the surveys capture multiple dimensions of the collaborative networks that are not accessible through existing data such as bibliometrics.

The survey instruments collected network data using a series of *name generator* and *name interpreter* questions. Respondents were first asked to write in the names of key collaborators or advisors in research collaboration as well as advice and support networks into five name generator questions. 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" and individuals in two types of advice scenarios – those with whom they talk about career advice and with whom they discuss departmental matters. Although, the first three (research) networks are mutually exclusive, there is some overlap between the research and advice networks. Once the survey respondent provided names in each of the five name generator questions, the names were piped forward into a series of *name interpreter* questions, for which the respondent was asked to respond. Name interpreter questions addressed the type of the collaboration undertaken with the collaborator, details about the level of relationship and origin of acquaintance, communication frequency, superiority of ties in terms of seniority, and grant getting ability, resources received from ties, and general demographics. Alter-level data are converted to respondent attribute data through the aggregation of mean or sum values within an individual's network, depending on desired variable structure. For the purposes of this dissertation research, details about collaborative networks—strength of collaborative ties, superiority of collaborators in terms of their seniority and grant getting ability, and resources received from collaborators are included only.

The surveys were implemented online using Sawtooth Software®, posted as a webpage and completed by participants online. 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. The complex nature of the name generator and interpreter questions required a specialized electronic platform where duplicate name entries were automatically removed and piped forward where they were embedded within the appropriate name interpreter questions. In addition to the network questions, respondents were asked about their research activities, including dollar amount of largest grant, awards, publications, salary, work environment, satisfaction, and detailed demographic and academic background. Overall, the surveys took between 30 and 45 minutes to complete.

In the first phase survey in 2007, 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 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 were included. The final analysis sample size was therefore 1,598 surveys as shown in Table 1. 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). Responses were fairly evenly distributed across gender (46% women) and field (18% of respondents are from biology, 18% from chemistry, 13% from computer science , 16% from earth and atmospheric sciences, 17% from electrical engineering, and 17% from physics) . The distribution of rank is nearly proportionate to the population (27% assistant professor, 28% associate professor, and 45% full professor.).

TABLE I. OVERALL RESPONSES OF THE FIRST PHASE SURVEY

Number of complete responses	1577
Number of partial or break-off with sufficient info	21
Number of break off or partial with insufficient information	219
Number of explicit refusal	59
Number of nothing was ever returned	1615
Number of selected respondent screened out of sample	176

The second survey was conducted in 2010. The purpose of this second survey was to gather longitudinal data from egos' who responded to the first survey in 2007. The content of this follow on survey is essentially identical to that of the first survey with minor alterations to the text in order to account for changes. Of particular importance was to get updates on the following information: rank and tenure, work satisfaction, salary, grants, and networks. This dissertation uses data from both points in time. The two year panel data enables analysis on how network structure in 2007 affect rewards and recognition, and satisfaction in 2010. The population for the second survey was derived from the respondents of the 2007 phase I ego survey. The final sample size of the follow-on survey was 1498. This was based upon the 1598 survey responses from the initial 2007 survey. Of those 1598 responses, 100 surveys were eliminated due to invalid email addresses. The overall response rate of the follow-on survey, calculated using the RR2 method of the American Association for Public Opinion Research (AAPOR) is 51%. This is the weighted response as well according to AAPOR. Matching the 2007 and 2010 survey responses resulted in a final panel of 765 observations as shown in Table 2.

TABLE II. OVERALL RESPONSES OF THE FOLLOW ON SURVEY

Number of complete responses	765
Number of break off or partial with insufficient information	46
Number of explicit refusal	11
Number of implicit refusals	7
Number of other non-refusals	4
Number of non-responses (nothing returned)	665

Responses were fairly evenly distributed across gender (48% women) and field (19% of respondents are from biology, 19% from chemistry, 15% from computer science , 19% from earth and atmospheric sciences, 12% from electrical engineering, and 15% from physics).The distribution of rank is nearly proportionate to the population (27% assistant professor, 27% associate professor, and 46% full professor).

Due to listwise deletion, primarily because of missing data in the dependent and independent variables, the final sample sizes used in this dissertation study are lower than 765. Nevertheless, descriptive results for the sample used in this study are not significantly different from the full panel of 765 responses. In the next section, the extent and pattern of missing data in the sample is explored for the important dependent and independent variables. Techniques to replace missing data are also discussed.

4.3. Extent and pattern of missing data

Missing data is a common problem in research particularly in social sciences (Juster and Smith, 1998). By missing data, one refers to data that are missing for some variables, and for some cases (Allison, 2000). Missing data poses a problem because loss of data can lead to loss of statistical power and bias in parameter estimates (Roth, 1994). When data are missing, standard analysis techniques cannot immediately be used to analyze an incomplete dataset because most statistical procedures require value for each variable (Allison, 2000).

When faced with missing data, it is important to determine its extent and pattern because these factors impact the validity of research findings. The extent of missing data refers to the percentage of cases with missing data on a given variable. Cohen and Cohen (1983) suggested that when up to 10% of cases have missing data on a given variable, the extent of missing data is not extensive, and thus the variable should be retained and the missing data should be treated. Hertel (1976) suggested that a variable should be deleted when 15% or more of the cases have missing data on that variable. Raymond and Roberts (1987) suggested that a variable should be deleted when 40% or more of the cases have missing data on a given variable.

Most of the dependent and independent variables used in the study have less than 14% of cases that have missing values (see table 3). The two dependent variables –satisfaction with rewards at time 2 and satisfaction with reputation of department and institution at time 2 have 5.1% and 2.88% of cases with missing data respectively. Six out of the eight network variables have approximately 11% of cases as missing. Network constraint has only 3.27% of the cases as missing. Among the reward variables, dollar amount of largest grant at time 2 has 13.86% of its cases as missing, and salary at time 2 has 7.58% of its cases as missing. Since, all the variables have less than 14% of their cases as missing; they may be retained and treated. Roth (1994) suggested that regression imputation technique may be used to replace missing data when less than 20% of cases are missing.

TABLE III. EXTENT OF MISSING DATA IN PERCENTAGES FOR IMPORTANT VARIABLES IN THE STUDY

	N	Percentage observed	Percentage missing
Collaborative network constraint	740	96.73	3.27
Number of strong collaborative ties by duration	683	89.28	10.72
Number of strong collaborative ties by frequency	676	88.37	11.63
Number of strong collaborative ties by close friendship	683	89.28	10.72
Number of senior collaborators	683	89.28	10.72
Number of better grant getters	680	88.89	11.11
Number of collaborators who provide introductions	681	89.02	10.98
Number of collaborators who provide nominations	681	89.02	10.98
Largest dollar amount of grants at time t2 (in 10000 dollars)	659	86.14	13.86
Salary at time t2 (in 10000 dollars)	707	92.42	7.58
Satisfaction with rewards at time 2	726	94.90	5.10
Satisfaction with reputation of dept. and inst at time2	743	97.12	2.88

Tabachnick and Fidell (2001), and Kline (1998) suggested that the pattern of missing data is more important than the extent of missing data because it has a larger impact on generalizability of results. When the probability of missing data on a given variable is independent of the values of other variables in the dataset, the data are assumed to be missing completely at random (MCAR). One way to explore the pattern of missing data is to create a missing data dummy code (missing value=0; non missing value=1), and correlate it with other variables in the dataset. A significant strong correlation suggests that missing data are related to other variables in the dataset, and therefore cannot be MCAR.

The above technique was adopted in this study for finding the pattern of missing data. Firstly, missing data dummy code was created for all the eight network variables. For example, network constraint was recoded as 0 = missing value; 1= non-missing value. Similar recoding was done for strong ties by duration, frequency, and close friendship; superior ties by seniority and grant getting ability; and resources received from alters in the form of introductions and nominations. These eight recoded dummy variables were then correlated with dependent variables such as satisfaction with rewards at time 2, satisfaction with reputation of the department and institution at time 2, and reward variables such as amount of largest grant at time 2, and salary at time 2. Correlation findings suggest that none of the recoded dummy network variables were significantly correlated with the satisfaction and reward variables, suggesting that the missing network data are completely at random (see table 4).

Additionally, missing data dummy code was created for the two dependent variables and two reward variables such as satisfaction with rewards at time 2, satisfaction with reputation of the department and institution at time 2, amount of largest grant at time 2, and salary at time 2 were also recoded. For example, satisfaction with rewards at time 2 was recoded as 0 = missing value; 1= non-missing value. Similar recoding was done for satisfaction with reputation of the department and institution at time 2, amount of largest grant at time 2, and salary at time 2. These four variables were then correlated with the eight network variables. Correlation findings suggest that none of recoded dummy satisfaction and reward variables were significantly correlated with the network variables, except recoded dummy grant large variable and network constraint. This suggests that the missing data on the satisfaction variables and the salary variable are completely at random (see table 5). However, cases missing for the grant large variable may be missing in a systematic manner because it is negatively correlated with network constraint. When up to 15% of cases are missing in a systematic manner, then regression imputation may be an appropriate technique to replace the missing values (Roth, 1994).

A second approach to explore whether missing data is completely at random involves creating a missing data dummy code and computing t test comparisons between respondents and non-respondents to examine whether they are different on any of the variables in the data set (Acock, 1997; Fox et al, 2005). A significant difference between respondents and non-respondents indicates an association and rules out the possibility that the data are missing completely at random.

This second approach of t test comparison between respondents and non-respondents was also conducted in this study. Missing data dummy code was created for the two dependent variables. In other words, satisfaction with rewards at t2 was recoded as 0= missing value; 1= non-missing value. Similar recoding was done for satisfaction with reputation of department and institution at t2. The goal was to determine that whether the scientists who responded to satisfaction with rewards differ on network characteristics and rewards compared to those scientists who did not respond to satisfaction with rewards. There were 39 scientists who did not respond to satisfaction with rewards, and 22 scientists who did not respond to satisfaction with reputation of department and institution. T test comparison between scientists who responded to satisfaction with rewards and scientists who did not respond to satisfaction with rewards was computed. T test results reveal that scientists who responded to satisfaction with rewards did not differ significantly in their network characteristics and rewards compared to scientists who did not respond to satisfaction with rewards (see table 6). When there are no significant differences between people who responded and people who did not respond, one may assume that the data are missing completely at random (Acock, 1997; Fox et al, 2005). T test comparison between scientists who responded to satisfaction with reputation and scientists who did not respond to satisfaction with reputation was also computed. Results suggest that scientists who responded to satisfaction with reputation did not differ significantly in their network characteristics and rewards compared to scientists who did not respond to satisfaction with reputation (see table 7). It is reasonable to assume that missing data on the satisfaction variables are completely at random, and may be retained and treated.

4.3.1. Techniques for handling missing data

Missing data can be handled by either deletion or imputation techniques. Deletion techniques involve excluding subjects with missing data from statistical calculations. Imputation techniques involve calculating an estimate of each missing value and replacing, or imputing, each value by its respective estimate. Deletion techniques are criticized because they reduce the sample size and power of generalizability (Little and Rubin, 1987; Roth, 1994; Tabachnick and Fidell, 2001). Imputation involves replacing missing data with estimates that are based on the values of other variables in the dataset. Unlike deletion, imputation retains sample size, thereby minimizing attenuation of statistical power.

There are several types of imputation techniques such as sample and group mean substitution, case mean substitution, hot deck imputation, and regression imputation. Sample mean and group mean substitution involves replacing a missing data point for a case on a variable with the sample mean score of that variable (Acock, 1997; Kline, 1998; Tabachnick and Fidell, 2001). This technique assumes that missing and available data are normally distributed and that the best guess for a missing score is the mean of that variable (Acock, 1997). Although this technique preserves data, it tends to ascribe values that are more likely to be closer to the values of other cases than to the real missing values. Therefore, the use of sample and group mean substitution techniques should be restricted to situations in which the extent of missing data is very small (Tabachnick and Fidell, 2001).

Another type of imputation technique is case mean substitution which ascribes the subject's mean score based upon the items that are present to the missing score for that subject (Raymond, 1986). This strategy assumes that for any given case, the score on any data point is closely related to the score on the remaining data points. The primary advantage of this technique is that it acknowledges differences across cases by using data provided by a case to estimate its own missing data rather than using data provided by other cases (Fox et al, 2005). However, case mean substitution may not be appropriate for imputing missing data at the variable level because the combination of variables within a case often does not represent a single concept (Fox et al, 2005).

Hot deck imputation involves imputing a missing data point with the score from a similar case in the sample (Roth and Switzer, 1995). Proponents of hot deck imputation suggest that it is an appropriate technique because missing data are replaced by realistic score that preserve variable distribution (Kline, 1998; Roth, 1994). However, Ford (1983) suggested that hot deck procedures are based on common sense than on theory. In addition, hot deck imputation can be very complex and unwieldy when matching is made on a large number of variables or items (Roth, 1994). Other disadvantages of hot deck imputation include difficulty in estimating standard errors (Roth, 1994). Hot deck imputation is appropriate when the data are missing in a systematic manner (Roth, 1994).

Multiple imputation provides an empirical alternative to single imputation techniques that adds variability to the imputation process by creating different estimates for a single missing datum (Acock, 1997). It is best described as a three step procedure in which several complete data sets are simulated, each dataset is analyzed separately and the results of all analyses are pooled together to provide one result (McCleary, 2002). There are several possible approaches to impute missing data in the first step of multiple imputation. These include imposing a probability model such as a multivariate normal distribution or a log linear model to estimate missing data. An alternate approach involves using a regression equation (Yuan, 2004). In the next step, a random numbers generator is used to simulate a set of residuals that are added to the regression predictions, which then replace the missing values. Multiple imputation is superior to list wise deletion, pairwise deletion, and mean substitution; and is robust to violations of non-normality of the variables. Disadvantages of multiple imputation include complex and time intensive computations that may be complicated by the fact that the procedure is not available on conventional statistical packages.

The last but not the least, regression imputation uses knowledge of available data to predict the values of missing data. It is based on the principle that, if missing data variables can be predicted by other variables in the dataset, the resulting regression equation can be used to predict missing values for incomplete cases (Acock, 1997; Patrician, 2002; Tabachnick and Fidell, 2001). Regression imputation strives to methodologically estimate the missing data and thus is relatively objective (Tabachnick and Fidell, 2001). Empirical studies indicate that regression imputation is more accurate than other approaches (Raymond and Roberts, 1987). One disadvantage of regression imputation stems from the possibility that variables used to predict missing values may not be good predictors, and may therefore lead to inaccurate estimation of missing values. One way to minimize this problem is to use only the best predictor or set of predictors in the regression model that contribute to the largest percentage of the explained variance in the regression model (Acock, 1997).

Raymonds and Roberts suggested that regression imputation is most useful when data are 10%-40% incomplete. Roth (1994) suggested that regression imputation is appropriate when up to 20% of cases are missing completely at random, and up to 15% of cases are missing in a systematic manner. As in the case of this study, 14% of cases are missing completely at random for all the independent and dependent variables, it may be appropriate to apply regression imputation to replace missing values. In the next chapter, OLS regression models predicting satisfaction with rewards and satisfaction with reputation will be run both with missing data and with replaced missing data using regression imputation. The results of both models will be compared and explained.

TABLE IV. CORRELATION BETWEEN MISSING NETWORK DATA AND BOTH KINDS OF SATISFACTION AT T2

		1	2	3	4	5	6	7	8	9	10	11	12
1	Satisfaction with rewards at time 2	1.00											
2	Satisfaction with reputation at time2	0.46	1.00										
3	Salary at time t2 (in 10000 dollars)	0.21	0.15	1.00									
4	Largest dollar amount of grants at time t2 (in 10000 dollars)	-0.02	-0.04	0.04	1.00								
5	Sum of awards at time t1	0.03	0.07	0.11	0.08	1.00							
6	constraint recode missing	0.07	-0.02	-0.02	-0.04	-0.02	1.00						
7	strong ties by duration recode missing	0.02	-0.07	-0.06	-0.05	-0.04	0.53	1.00					
8	strong ties by frequency recode missing	0.03	-0.05	-0.05	-0.04	-0.04	0.51	0.95	1.00				
9	strong ties by friendship recode missing	0.02	-0.07	-0.06	-0.05	-0.04	0.53	1.00	0.95	1.00			
10	senior ties recode missing	0.02	-0.07	-0.06	-0.05	-0.04	0.53	1.00	0.95	1.00	1.00		
11	better grant getting recode missing	0.03	-0.06	-0.06	-0.05	-0.03	0.52	0.98	0.95	0.98	0.98	1.00	
12	introductions recode missing	0.02	-0.05	-0.06	-0.05	-0.05	0.52	0.99	0.95	0.99	0.99	0.98	1.00
13	nominations recode missing	0.02	-0.05	-0.06	-0.05	-0.05	0.52	0.99	0.95	0.99	0.99	0.98	1.00

TABLE V. CORRELATION BETWEEN MISSING SATISFACTION, AND REWARD OUTCOMES AND NETWORK VARIABLES

		1	2	3	4	5	6	7	8	9	10	11	12
1	Collaborative network constraint	1.00											
2	Number of strong collaborative ties by duration	-0.32	1.00										
3	Number of strong collaborative ties by frequency	-0.16	0.55	1.00									
4	Number of strong collaborative ties by close friendship	-0.12	0.43	0.41	1.00								
5	Number of senior collaborators	-0.20	0.26	0.13	0.11	1.00							
6	Number of better grant getters	-0.14	0.23	0.12	0.14	0.51	1.00						
7	Number of collaborators who provide introductions	-0.17	0.45	0.39	0.34	0.21	0.24	1.00					
8	Number of collaborators who provide nominations	-0.13	0.37	0.24	0.26	0.18	0.17	0.43	1.00				
9	satisfaction with rewards t2 recode missing	0.03	0.03	-0.01	0.03	0.06	0.01	0.03	-0.02	1.00			
10	satisfaction with reputation t2 recode missing	-0.02	0.01	0.00	0.02	0.04	-0.03	-0.03	-0.04	0.64	1.00		
11	grant large at t2 recode missing	-0.10	0.05	0.05	0.01	0.07	0.03	0.01	-0.01	0.25	0.32	1.00	
12	salary at t2 recode missing	0.01	0.04	-0.02	-0.02	0.05	-0.01	-0.01	-0.04	0.45	0.48	0.29	1.00

TABLE VI. T TEST COMPARING SCIENTISTS WHO RESPONDED TO SATISFACTION WITH REWARDS AT T2 AND WHO DID NOT ON NETWORK CHARACTERISTICS AND REWARDS

						95% confidence interval of the difference	
	t	df	Sig.	Mean difference	Std error difference	Lower	Upper
Collaborative network constraint	-.737	738	.461	-.030	.041	-.111	.050
Number of strong collaborative ties by duration	-.821	681	.412	-.335	.408	-1.137	.466
Number of strong collaborative ties by frequency	.259	674	.795	.077	.296	-.505	.659
Number of strong collaborative ties by close friendship	-.671	681	.503	-.193	.288	-.758	.372
Number of senior collaborators	-1.581	681	.114	-.506	.320	-1.134	.122
Number of better grant getters	-.294	678	.769	-.080	.274	-.618	.457
Number of collaborators who provide introductions	-.884	679	.377	-.270	.305	-.869	.329
Number of collaborators who provide nominations	.584	679	.559	.116	.198	-.274	.505
Salary at time t2 (in 10000 dollars)	-.794	705	.427	-.922	1.161	-3.202	1.358
Largest dollar amount of grants at time t2 (in 10000 dollars)	.056	657	.956	5.715	102.695	-195.935	207.365
Satisfaction with reputation at time2	1.154	741	.249	.180	.156	-.126	.487

TABLE VII. T TEST COMPARING SCIENTISTS WHO RESPONDED TO SATISFACTION WITH REPUTATION AT T2 AND WHO DID NOT ON NETWORK CHARACTERISTICS AND REWARDS

						95% confidence interval of the difference	
	t	df	Sig.	Mean difference	Std error difference	Lower	Upper
Collaborative network constraint	.515	738	.607	.027	.053	-.076	.131
Number of strong collaborative ties by duration	-.386	681	.700	-.208	.540	-1.268	.852
Number of strong collaborative ties by frequency	.038	674	.970	.014	.381	-.733	.762
Number of strong collaborative ties by close friendship	-.642	681	.521	-.244	.380	-.991	.503
Number of senior collaborators	-.919	681	.358	-.390	.424	-1.221	.442
Number of better grant getters	.720	678	.472	.261	.362	-.450	.971
Number of collaborators who provide introductions	.696	679	.486	.281	.403	-.511	1.073
Number of collaborators who provide nominations	1.167	679	.244	.306	.262	-.209	.821
Salary at time t2 (in 10000 dollars)	.500	705	.617	1.152	2.303	-3.370	5.673
Largest dollar amount of grants at time t2 (in 10000 dollars)	-.499	657	.618	-98.840	197.998	-487.625	289.946
Satisfaction with rewards at time 2	-.989	724	.323	-.389	.393	-1.161	.383

4.4. Measures

4.4.1. Satisfaction

The primary interest in the modeling section is to determine how networks lead to satisfaction through fulfillment of objective rewards and recognition. Two dependent variables are used to measure satisfaction: satisfaction with rewards and satisfaction with reputation of department and institution. *Satisfaction with rewards* is measured through three items: satisfaction with salary, satisfaction with reward system at the institution, and satisfaction with department's reward allocation for productivity. Each of these three items were measured by a four point scale (1=very dissatisfied to 4=very satisfied). The reliability of these three indicator variables and whether or not they contribute significantly in measuring satisfaction with rewards was tested through confirmatory factor analysis (CFA) in Amos version 19[1]. CFA results suggest that the three observed or indicator variables (satisfaction with salary, satisfaction with reward system at the institution, and satisfaction with department's reward allocation for productivity) were reliable and contributed significantly in the measurement of satisfaction with rewards. Their factor loadings were (0.79, 0.91, 0.79) respectively. Before conducting confirmatory factor analysis, reliability analysis was also done in SPSS. The three indicator variables that measure satisfaction with rewards had an acceptable cronback's alpha of 0.827. Descriptive statistics suggest that the average values for satisfaction with salary, satisfaction with reward system at the institution, and satisfaction with department's reward allocation for productivity are 2.63, 2.40, and 2.52 respectively. Histograms and box plot diagrams reveal that all of the three indicator variables that measure satisfaction with rewards are normally distributed.

The second dependent variable *satisfaction with reputation of department and institution* is measured by two observed or indicator variables: satisfaction with the reputation of the department, satisfaction with the reputation of the institution. Each of these two items were measured by a four point scale (1=very dissatisfied to 4=very satisfied). Confirmatory factor analysis suggests that these two indicator variables were reliable and they contributed significantly in the measurement of satisfaction with reputation of department and institution. Their factor loadings were (0.83, 0.79) respectively. Reliability analysis results from SPSS suggested that the three indicator variables that measure satisfaction with reputation of

[1] Amos is an easy to use program for visual SEM. With Amos, one can easily specify, view, and modify their model by using simple drawing tools. Amos quickly does the computations and displays the results.

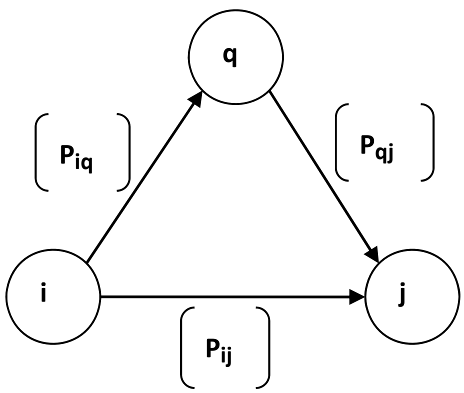
department and institution had an acceptable cronback's alpha of 0.816. Descriptive statistics suggest that the average values for satisfaction with the reputation of department, and satisfaction with reputation of the institution are 2.68, 2.76 respectively. Histograms and box plot diagrams reveal that the two indicator variables that measure satisfaction with reputation of department and institution are normally distributed.

4.4.2 Network variables

The focus of this research is the effect of networks on satisfaction with rewards and satisfaction with reputation of department and institution through fulfillment of rewards and recognition. Four network properties are measured: network constraint, strength of ties, superior ties, and resources received from network ties. These four network properties are measured for a specialized type of network---collaboration network. A detailed description of the four network measures is below.

Network constraint was obtained from the response to a questionnaire item which asked respondents how many of their named collaborators knew each other on a personal basis. Respondents were provided a matrix of names of all collaborators that they had entered in the survey and asked to indicate if each pair of collaborators knows each other on a personal basis. The basic premise of the concept of network constraint is that when alters are well connected to one another, they constrain opportunities for the ego as they have enough alternatives other than the ego (Hanneman, 2005; Marin and Wellman, 2009). In other words, network constraint taps the extent to which ego's connections are to others who are connected to one another. It measures how much do the alters constrain the ego. Constraint is calculated by summing the degree to which each of the alters is connected to others in the network. Previous research defines constraint as the extent to which all of ego's relational investments directly or indirectly involve a single alter (Burt, 1992, Borgatti et al., 1998). Constraint is measured as a combination of degree, density and hierarchy. Constraint is (1) high in small networks because there are few alters to provide information; (2) high in dense networks because alters are connected to one another in a type of echo chamber that provides little new information or opportunities; and (3) high in hierarchical networks organized around a single alter who has considerable structural advantage over the ego (Burt, 1992, 1998). This study calculated constraint using the following formula embedded in *Analytictech's E-Net software. The formula is as follows: Cij = (pij +Σq piq pqj) 2,* where ego i is constrained by alter j to the extent that i reaches out to q who in turn invests in j and, where q is not equal to i or j, *pij* = Z*ij* / Σ*q* Z*iq* (where *Pij* is the proportion of i's network time and energy invested in contact j), and Z*ij* is the strength of the relationship between contact i and j. The sum Σ*q Piq Pqj* is the portion of i's relation invested in alter q who invests in alter j. Summing these constraints for all alters yields the overall network constraint C as shown in Fig 1.

Fig 10. Ego network constraint



Strength of ties is measured by three indicator or observed variables: frequency of interaction, duration of interaction, and close friendships for collaborative network. To measure *frequency of interaction*, the number of ties which whom the ego scientist interacts once a week or more was created. This variable was computed in response to the survey question which asked the respondent, how frequently they interacted with their ties on a personal basis over the past two years. The response options were: 1= at least daily, 2=almost weekly, 3=almost monthly, 4=less often. A dummy variable at the ties level was then created wherein the response option at least daily and almost weekly was treated as 1 and almost monthly and less often treated as 0, and aggregated for each ego scientist. To measure *duration of interaction,* the number of ties the ego scientist has known for three years or more was computed. This variable was computed in response to the survey question which asked the respondents, how long have they known their ties. The response options were: 1=less than 3 years, 2=3-6 years, 3=more than 6 years. A dummy variable at the ties level was created wherein the response options 2 and 3 were treated as 1, and response option 1 was treated as 0, and then aggregated for each ego scientist. *Close* *friendships* was created in response to the survey question which asked the respondent to indicate whether the tie was a close friend. This variable was then aggregated for each ego scientist for the purpose of the current study.

Confirmatory factor analysis results suggest that the three observed or indicator variables (frequency of interaction, duration of relationships and close friendships) were reliable and contributed significantly in the measurement of strong ties. Their factor loadings were (0.62, 0.88, 0.53) respectively. Reliability analysis results in SPSS found that these three indicator variables that measure strong ties also had an acceptable cronback's alpha of 0.718.

Superior alters in ego's network is measured by two indicator or observed variables: number of seniors and number of better grant getters compared to the ego. Seniors was created using response to a survey question which asked the respondents to indicate whether their network tie is a senior. This variable was then aggregated for each ego. On average, ego scientists have 2 collaborators whom they consider as their senior. Better grant getters was created using response to a survey question which asked ego scientists to indicate whether their network tie has a better, same, or worse ability to obtain grant funding as compared to them. Specifically, the response options were 1=much better than me, 2=about the same as me, 3=much worse than me. A dummy variable was computed wherein the response option 1 was treated as 1, and options 2 and 3 treated as 0, and then aggregated for each ego. Confirmatory factor analysis results suggest that the two observed or indicator variables (seniors and better grant getters) were reliable and contributed significantly in the measurement of superior ties. Their factor loadings in Amos version 19 were (0.82, 0.62) respectively. Reliability analysis results in SPSS found that these two indicator variables had cronback's alpha of 0.671.

Resources received from networks is measured by two indicator or observed variables namely number of ties who introduced the ego scientist to potential collaborators, and number of ties who nominated the ego scientist for awards or invited them to speak. Introductions was created using response to a survey question which asked the respondents to indicate whether their network tie introduced to potential collaborators outside of their institutions. This variable was then aggregated for each ego. Nominations for awards or invitations to speak was created using response to a survey question which asked the respondents to indicate whether their network tie nominated them for awards or invited them to speak. This variable was then aggregated for each ego. Introductions and nominations are reliable indicators of resources received and contribute significantly to its measurement. CFA indicates that their factor loadings are (0.6, 0.67) respectively.

4.4.3. Objective rewards, and recognition

The institution of science has developed an evaluation system to give recognition and rewards to scientists who have made significant contributions to the existing stock of knowledge. Recognition and rewards are indicators of scientist's merit or worth. Various forms of recognition and rewards as discussed in the literature such as awards, research funding, and salary (Cole and Cole, 1967; Cole, 1971; Glaser, 1963). The achievement of rewards and recognition is considered a principal motive for scientific collaboration. Specifically, scientists are motivated to collaborate because they expect collaboration to result in greater levels of research production, recognition and rewards (Gustin, 1971). Hagstron (1966) refer to collaboration as gift exchange wherein scientists give away their knowledge for free and in return receive gifts in the form of new knowledge, and recognition such as awards, research funding, and other prizes. When expectations of recognition and rewards are met as result of collaboration, then the scientist expresses a higher level of satisfaction. However, all collaborative ties may not result in the same level of recognition and rewards, and consequently satisfaction. Some may result in more, while others may result in less recognition and rewards. For instance, previous research suggests that collaboration with higher status scientists facilitates ego scientist's ability to receive more rewards and recognition because these scientists may play a bigger role in allocating scientific rewards (Crane, 1965). In addition to higher status scientists, several other characteristics of collaboration network such as strength of ties, network constraint, and resources received from collaborative ties may also affect achievement of recognition and rewards, and hence satisfaction. Several underlying processes or mechanisms link collaborative networks to recognition and rewards.

This study uses three measures of recognition and rewards: salary, dollar amount of largest grant, and awards. ***Salary*** is captured in one survey question asking respondents the dollar amount of their salary, and ***dollar amount of largest grant*** is captured in one survey question that asks the respondents about the dollar amount of largest grant they received. Four questions about ***awards*** were asked in the survey. The first question pertained to whether or not the ego scientist received a best paper or dissertation award, second question asked whether or not the scientist received a NSF career grant, third question asked whether or not the scientist received a NSF fellowship, fourth question asked whether or not the scientist received a young investigator award. A variable was then created which summed the responses in all of the four questions.

4.4.4. Control variables

Non network control variables that are included in the study are: receipt of organizational resources, and perceived influence in the department. To measure the ***receipt of organizational resources***, the phase 1 survey asked respondents to indicate whether they had received the following resources from their department in the past two academic years(travel money for conferences, additional laboratory space, equipment and technical support, software upgrades, special classroom facilities, administrative support for grant writing and grant management; 1=received; 0=not received). From response to this item, the total amount of organizational resources received by the respondent from their departments was summed. Being supported in the department in terms of research support, travel support, technology support, and clerical support leads to higher levels of satisfaction (Rosser, 2004, 2005).

Previous studies have shown that faculty members who spend a greater percentage of their time on teaching in research I universities have a lower level of work satisfaction (Liu, 2001). One commonly held view among faculty member in research I universities is that teaching and service/committee work takes away huge chunk of time away from research and scholarly activities (Rosser and Tabata, 2010). Although teaching evaluations and service is perceived as an important component of promotion and tenure review, it may not lead to satisfaction in research I universities (Hagedorn, 2000). Faculty members who spend more time in teaching may be less satisfied. As a result, this study includes number of courses taught or co taught as a control variable.

Several studies have reported a strong positive correlation between faculty size and departmental prestige (Burris, 2004; Lindzey and Coggeshall, 1982; Abbott, 1972; Ehrenberg and Hurst, 1996). Greater number of faculty is a resource that facilitates the creation and maintenance of interdepartmental networks, and enhances departmental reputation (Burris, 2004). If number of faculty is positively related to departmental reputation, it is reasonable to presume that department faculty size may be positively related to satisfaction with departmental reputation. As a result, this study includes faculty size as one of the control variables as one expects faculty size to be related to satisfaction.

Several other ***control variables*** are also included. A brief discussion of previous literature that has explored the role of these controls on satisfaction is provided. These control variables can be categorized as demographic variables (***gender, race***), and career related variables (***rank***), and ***academic fields***. Previous research suggests that women faculty tend to have lower satisfaction with pay compared to their male counterparts (Tang and Talpade, 1999). Olsen and colleagues (1995) found that women faculty report receiving receive lower levels of recognition and support compared to men faculty. As a result, one expects gender to be strongly related to satisfaction. Previous studies have concluded that minority faculty has a lower level of satisfaction compared to other faculty members (Antonio, Cress, and Astin, 1997; Olsen et al 1995). Hence, this study includes race as one of the control variables. Full Professors report a higher level of satisfaction compared to assistant professors (Oshagbemi, 1997). Senior faculty members are more satisfied when they receive intrinsic rewards as a result of their scholarly productivity, whereas junior faculty are more satisfied when they receive recognition and support from colleagues (Olsen, 1993). Hence, one expects that rank may be significantly related to satisfaction. Academic fields have also been found to affect satisfaction among academic faculty. Previous research has discussed that faculty members in one academic field resemble each other more closely than faculty members in other fields (Smart et al, 2000). Moreover, satisfaction is found to be significantly related to academic field (Neumann and Finaly 1991; Terpstra and Honoree 2004). In light of these findings, this study includes six fields of science and engineering: physics, chemistry, biology, earth and environmental science, electrical engineering, and computer science as control variables. ***Research production*** is also controlled for. It is captured in one survey question that asks respondents about the number of peer reviewed ***journal articles*** published over the past two academic years.

4.5. Method: Structural equation modeling

The first step in the methods section is a review of univariate and bivariate statistics. Univariate statistics describes and summarizes individual variables. It looks at the range of values and central tendency (mean, median, and mode) of the variables. Bivariate statistics compares two variables. Specifically, it is helpful in examining the association between two variables. One form of bivariate analysis is correlation. There are two characteristics of correlation: direction and strength. Direction may be either positive or negative. Strength may either be weak, moderate, or strong. Correlation coefficient, r, also known as Pearson correlation ranges from -1 to +1, which indicates the direction and strength of correlation between two variables. The closer r is to 1, the stronger is the correlation (Agresti and Finlay, 1999). The next step is to run an ordinary least square regression as both the dependent variables are normally distributed. Specifically, to predict satisfaction with rewards, and satisfaction with reputation of department and institution, independent variables such as network variables, and reward variables are used while controlling for non-network, demographic and individual background variables. This study takes a step further by using structural equation modeling because of the complexity of the theoretical model, presence of multiple independent and dependent variables, and the effect of independent variables on the dependent variable through mediator variables.

The basic goal of structural equation modeling (SEM) is to provide quantitative test of a theoretical model hypothesized by a researcher. In other words, theoretical models can be tested in SEM that hypothesize how sets of variables define and measure constructs and how these constructs are related to each other. SEM can test two types of models: 1) confirmatory factors models (CFA) and 2) path models. In CFA, the researcher specifies which observed variables measure each latent variable. The reliability and significance of the observed variables are then tested. Arrows directed from a latent variable to observed variable denotes the relationship between them and are interpreted as factor loadings. The second component of SEM is the path model which permits theoretically meaningful relationships among variables than cannot be specified in a single additive regression model. Specifically, path analysis involves multiple observed and latent variables and the relationships among them. In path analysis, direct effect represents the effect of an independent variable on a dependent variable; indirect effect represents the effect of an independent variable on a dependent variable through a mediating variable; total effect presents the summation of direct and indirect effects (Schumacker and Lomax, 2004; Byrne, 2010).

In order to understand SEM, one needs to understand two types of variables: latent variables and observed variables. Latent variables (constructs or factors) are not directly observed or measured and hence are inferred from a set of observed variables which one measures using surveys. For example, in this study one of the independent latent variables is strong ties. The observed, measured or indicator variables used to define or infer this latent independent variable are the following: close friendships, frequency of interaction, and duration of interaction. Conceptually, a factor represents the common variation among a set of observed variables. Thus, for example, the latent independent variable in the study strong ties represents common variation among close friendships, frequency of interaction, and duration of interaction Similarly, the latent dependent variable in the study satisfaction with rewards represents common variation among satisfaction with salary, satisfaction with reward system at the institution, and satisfaction with department's reward allocation for productivity. Other latent variables in the study are superior ties and resources, each of which is measured by two observed variables. Once the latent variables are measured well by a given set of observed variables, then one specifies the structural equation model to indicate how the latent independent and dependent variables are related. This study hypothesizes a structural model based on predicting the effects of networks on satisfaction (latent dependent variable) mediated by rewards and recognition.

Detailed reasons for using SEM in this study are the following. First, it allows using multiple observed and latent variables to predict satisfaction. Basic statistical models utilize only a number of observed variables which are not capable of dealing with sophisticated theories being developed (Schumacker and Lomax, 2004). The theoretical model in this study is sophisticated as it represents an integration of social network theoretical perspective, social exchange theory, and expectancy theory of motivation to predict the effect of networks on satisfaction. Second reason for the use of SEM is that in this study, networks lead to satisfaction through the fulfillment of rewards and recognition. Thus, rewards and recognition mediates the relationship between networks and satisfaction. SEM permits the use of mediator variables through which independent variable affect the dependent variable (Lacobucci, 2008). Third reason involves the greater emphasis in SEM given to the validity and reliability of observed variables. Fourth, SEM is capable of assessing, correcting, and providing explicit estimates of measurement errors. Traditional multivariate methods are incapable of either assessing or correcting for measurement error (Byrne, 2010).

There are five steps or processes of SEM analyses which were followed in this study: 1) model specification, 2) model identification, 3) model estimation, 4) model testing, and 5) model modification. The first step, model specification involves using relevant theory to develop the model and specifying the relationships between parameters. In this study, the theoretical model to predict satisfaction uses a number of latent and observed variables. Given this, there are a number of measurement and structural model. Theory plays an important role in formulating structural equation model and guides the decision about which model to specify and test. This study uses a theoretical framework that integrates social exchange theory, network structural theory, and expectancy theory of motivation to predict the effect of collaboration networks on satisfaction. Exclusion of important variables or inclusion of unimportant variables may result in model misspecification. Misspecified models may result to biased parameter estimates. This bias is known as specification error. A number of procedures are available for the detection of specification error so that a model is more properly specified and evaluated. One such procedure is model modification procedure which is described later.

The second step, model identification involves imposing constraint on the model prior to the estimation of parameters. A number of different methods are available for avoiding identification problems. One such method is fixing the factor loading of one indicator variable for each latent variable to 1. This method of solving model identification is used in this study. The third step, model estimation involves the use of a particular fitting function. This study uses maximum likelihood (ML) function. If the variables are interval, scaled, and normally distributed as in the case of this study, then ML estimates and standard errors are appropriate. The fourth step is model testing. Once the parameter estimates are obtained for a specified SEM model, one should determine how well the data fits the model. In SEM, there are several model fit indices such as critical ratio which is the ratio of parameter estimate to the estimated standard error, comparative fit index (CFI), root mean square error of approximation (RMSEA) and so on. The fifth and last step of SEM is model modification. If the fit of the implied theoretical model is not as strong as one would like, then the next steps is to modify the model. Amos version 19 permits identification of required and optional paths in the model, thus generating a comparison of alternative nested models in a specification search (Schumacker and Lomax, 2004).

5. FINDINGS

5.1. Introduction

This study seeks to understand the effects of collaborative networks on satisfaction of academic scientists and engineers. In chapter three, four hypotheses were developed to test this effect. Each hypothesis is well grounded in the theoretical and empirical literature. Additionally, four propositions on the relationship between the four network properties were developed and presented. In chapter four, data, measures, and methods were discussed to conduct the empirical analyses. The purpose of this chapter is to present and interpret results of the four empirical methods used in this study---univariate, bivariate, OLS regression, and structural equation modeling.

The primary emphasis of this chapter is to present findings regarding the effects of networks on satisfaction through the mediating effects of rewards and recognition. Two types of satisfaction are considered in this study. They are satisfaction with rewards and satisfaction with reputation of department and institution. Structural equation modeling is conducted to understand the effects of four collaborative network properties on these two kinds of satisfaction through the mediating influence of rewards and recognition. Also, reported are OLS regression findings to show the relationships between networks and satisfaction, controlling for other non-network, demographic, and individual factors.

5.2. Empirical Model

The four hypotheses regarding the effects of networks on satisfaction mediated by rewards and recognition are graphically presented in fig 1. Each thick black solid arrow represents the hypotheses with number and direction. Although, not formally hypothesized, the thick red lines represent the direct effect of networks on satisfaction. The empirical model also includes four propositions depicting the relationship between network properties themselves. The propositions are also represented by solid arrows along with number and direction. The dotted lines refer to control relationships which are included to eliminate potential alternative explanations for the findings.

This research is a first step towards understanding the impact of collaborative networks on satisfaction of academic scientists and engineers mediated by rewards and recognition. Also, a novel theoretical approach of underlying social processes or social mechanisms linking networks, and rewards, and consequently satisfaction is applied in this study.

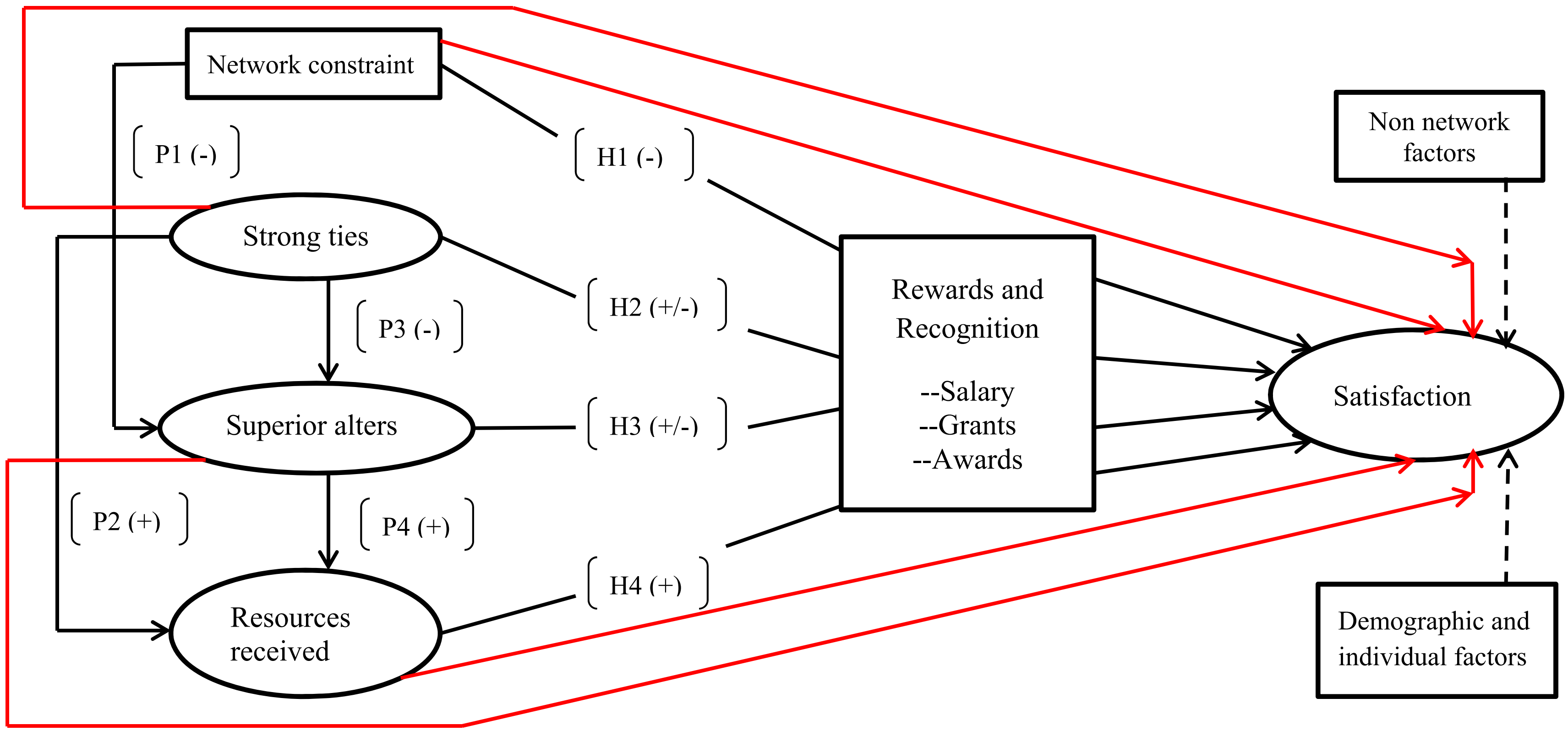
….Insert Fig. 11 about here….

5.3. Descriptive Statistics

The first empirical step is a review of the descriptive or univariate statistics for the studied sample. Information on the demographic variables is presented first (see table 1) followed by networks and non-network variables. Forty eight percent of the sample is females. According to the national science foundation's science and engineering indicators (2012), the number of women in academia increased more than eightfold between 1973 and 2008, from 10,700 to about 93,400, raising their share of all academic science and engineering doctoral employment from 9% to 34%. Women employed as full-time doctoral S&E faculty increased from 7% to 31%. In 2008, women constituted 21% of full professors, 37% of associate professors, and 42% of junior faculty. Going by these statistics, women scientists in this study sample are well represented.

Turning to other demographic indicators, descriptive statistics finds that whites comprise eighty four percent of the sample, while Asians, Hispanics, and Blacks comprise four, three, and one percent of the sample respectively. In 2008, underrepresented minorities (blacks, Hispanics, and American Indians/Alaska Natives) constituted about 9% of both total academic S&E doctoral employment and full-time faculty positions, up from 2% in 1973. Underrepresented minority groups have a relatively higher share of employment in other positions, which includes part-time positions, than in the full-time faculty and postdoc employment categories (Science and engineering indicators, NSF, 2012). The underrepresented minorities (Asians, Blacks, and Hispanics) together comprise 8% of this sample which reflects the NSF statistics reasonably well.

Fig 11. Empirical model



***H1 through H4 represent indirect effects of collaborative networks on satisfaction**
Red arrows represent direct effects of collaborative networks on satisfaction (direct effects are not hypothesized formally)
P1 through P4 represent propositions

Approximately half of the sample is full professors comprising forty seven percent of the sample. Associate professors and assistant professors comprise twenty four and twenty eight percent of the sample. The highest represented field is earth and environmental science comprising twenty percent of the sample followed by chemistry and biology, each of them comprises nineteen percent of the sample. Physicists and computer scientists each comprise fifteen percent of the sample. The lowest represented field is electrical engineering which comprises twelve percent of the sample.

Next, insights into size and shape of the collaborative networks for the academic scientists in this study are presented. Collaborative network variables can be grouped into four categories—1) collaborative network constraint, strong collaborative ties, superior collaborators, and resources received from collaborators. The average collaborative network constraint for scientists in the sample is forty nine percent. On average, the scientists in the sample have four collaborators whom they have known for more than three years. Perhaps scientists continue to collaborate with colleagues with whom they have collaborated in the past. The maximum possible number of collaborators whom the scientists reported of knowing more than three years is ten. Approximately three percent of the scientists reported knowing ten collaborators whom they have known for more than three years. On average, the scientists in the sample have two collaborators with whom they communicate weekly or more. Further, the scientists in the sample, on average have only one collaborator whom they consider their close friend. Also, thirty three percent of scientists in the sample did not have a single collaborator whom they considered their close friend. Perhaps scientists in the sample consider collaborative relationships as professional channels that provide them access to knowledge and recognition, not as sources of close friendships. This raises the question whether scientists develop functionally differentiated networks such that collaborative contacts and close friends are intentionally kept separately. More research is needed to explore this question.

Superior collaborators are measured by seniority, and better grant getting ability. On average, the scientists in the sample have two senior collaborators. Approximately, twenty three percent of the scientists in the sample do not have a single senior collaborator in their network. Perhaps this points to the fact that approximately half the sample is full professors. On average, the scientists in the sample have one collaborator who has a better grant getting ability as compared to them. Again, this points to the fact that half the sample comprises senior scientists.

Resources received from collaborators are measured by introductions by collaborators, and nominations for awards or invitations to speak from collaborators. On average, the scientists in the sample have one collaborator who provided the scientist with introductions to other potential collaborators, and one collaborator who nominated the scientist for an award or invited the scientist as a speaker.

In addition to collaborative networks, descriptive statistics (see table 2) contain information on objective outcomes such as salary both at time 1 and 2, largest grant amount (in dollars) both at time 1 and 2, number of peer reviewed publications at time 1 and 2, and awards at time 1[2]. The average salary of the scientists in the studied sample is $ 92500 and $ 105900 at times 1 and 2 respectively. On average, the largest grant amount of the scientists in the sample is $ 1489400 and $ 1454000 at times 1 and 2 respectively. The scientists in the sample publish 3.8 peer reviewed journal articles on average at time 1, and publish 4 journal articles on average at time 2. On average, the scientists in the sample receive 1 award at time 1.

TABLE VIII. DESCRIPTIVE STATISTICS—DEMOGRAPHICS

	N	Min	Max	Mean	SD
Demographic and individual control factors					
Female	765	0.00	1.00	0.48	0.50
Assistant Professor	765	0.00	1.00	0.24	0.43
Associate Professor	765	0.00	1.00	0.28	0.45
Full Professor	765	0.00	1.00	0.47	0.50
Physics	765	0.00	1.00	0.15	0.36
Chemistry	765	0.00	1.00	0.19	0.40
Biology	765	0.00	1.00	0.19	0.39
EAS	765	0.00	1.00	0.20	0.40
CS	765	0.00	1.00	0.15	0.35
EE	765	0.00	1.00	0.12	0.33
South or southeast Asian	765	0.00	1.00	0.04	0.19
Black/African American, not of Hispanic origin	765	0.00	1.00	0.01	0.10
Hispanic	765	0.00	1.00	0.03	0.16
White, not of hispanic origin	765	0.00	1.00	0.84	0.36
Satisfaction with rewards at t1	733	1.00	4.00	2.55	0.67
Satisfaction with reputation at t1	762	1.00	4.00	2.67	0.68

[2] Scientists were not asked about awards at time 2.

TABLE IX. DESCRIPTIVE STATISTICS—NETWORKS, AND NON-NETWORK CONTROL FACTORS

	N	Min	Max	Mean	SD
Network factors					
Collaborative network constraint	740	0.00	1.13	0.49	0.24
Number of strong collaborative ties by duration	683	0.00	10.00	4.47	2.32
Number of strong collaborative ties by frequency	676	0.00	9.00	2.30	1.64
Number of strong collaborative ties by close friendship	683	0.00	8.00	1.45	1.63
Number of senior collaborators	683	0.00	9.00	2.01	1.82
Number of collaborators who have a better grant getting capacity	680	0.00	9.00	1.69	1.55
Number of collaborators who provide introductions	681	0.00	9.00	1.73	1.73
Number of collaborators who provide nominations	681	0.00	6.00	0.86	1.13
Rewards and recognition					
Salary at time t1 (in 10000 dollars)	731	0.00	65.00	9.25	3.92
Salary at time t2 (in 10000 dollars)	707	0.00	77.50	10.59	4.59
Largest dollar amount of grants at time t1 (in 10000 dollars)	696	0.00	12000.00	148.94	659.44
Largest dollar amount of grants at time t2 (in 10000 dollars)	659	0.00	8000.00	145.40	440.80
Sum of awards at time t1	765	0.00	3.00	0.66	0.75
Non network factors					
Number of peer reviewed publications at time t1	762	1.00	7.00	3.82	1.66
Receipt of departmental resources	765	0.00	6.00	1.53	1.32
Number of courses taught/co-taught in past academic year at time t1	764	1.00	6.00	3.39	1.13
Department faculty size	765	1.00	177.00	36.56	27.15
Dependent variables: satisfaction at time 2					
Satisfaction with rewards at time t2	726	1.00	4.00	2.50	0.68
Satisfaction with reputation of department and institution at time t2	743	1.00	4.00	2.75	0.69

5.4. Correlation findings

Correlation findings are presented in five subsections. The first subsection discusses the relationship between collaborative network properties and satisfaction. In the second subsection, the relationship between collaborative network properties and rewards is discussed. The third subsection discusses the relationship between rewards and satisfaction. In the fourth subsection, the relationship between non-network, as well as control factors and satisfaction is discussed. Finally, the fifth subsection discusses the relationship between collaborative network factors themselves.

First, correlation findings on the relationship between collaborative network properties and satisfaction are presented below. Collaborative network constraint is negatively correlated with both kinds of satisfaction—satisfaction with rewards and satisfaction with reputation of department and institution. The negative correlation suggests that scientists engaged in collaborative exchange with a relatively powerful collaborator may report lower levels of satisfaction. Additionally, in a constrained network, the ego scientist may perceive himself or herself to be socially less valued and less legitimate. As a result of these negative perceptions, the scientists may report a lower level of satisfaction.

Other collaborative network properties such as being connected to a large number of senior collaborators and better grant getters are also negatively correlated with both kinds of satisfaction. The negative correlation may be explained from a social status perspective. Specifically, social status perspective argues that having a large number of high status collaborators lowers the status of the ego scientist and enhances the status of the high status collaborators. A loss of status may lead to negative perceptions such as being incompetent to achieve rewards and recognition, or being unable to reciprocate for the assistance offered by high status collaborators. In other words, the ego scientist engaged in collaborative exchange with high status collaborators may form negative perceptions about his or her capabilities, and may report a lower level of satisfaction.

Another negative correlation is found between strong collaborative ties by frequency and satisfaction with rewards. This finding suggests that scientists that have a large number of strong collaborative ties with whom he or she interacts weekly or more report a lower level of satisfaction with rewards. Perhaps, collaborative exchange with strong ties limits the exposure of the ego scientists to diverse actors and ideas essential for professional recognition and rewards. As a result, the ego scientist may report a lower level of satisfaction with rewards.

Secondly, in this paragraph, the findings on the relationship between collaborative network properties and reward outcomes are presented. Specifically, strong collaborative ties measured by duration and frequency are positively correlated with salary at time t2. In other words, scientists having a large number of strong collaborative ties that they have known for more than three years and with whom the scientists interact weekly earn higher salary. Resources received from collaborators in the form of nomination for awards are also positively correlated to both kinds of rewards -- salary and dollar amount of largest grant at time t2. This indicates that scientists who are nominated for awards by their collaborators are able to earn higher salary and receive large grants in terms of dollar amount. Further, senior collaborators and better grant getters are negatively correlated with salary at time t2. This means that scientists that are connected to a large number of higher status collaborators in terms of seniority and grant getting ability earn lower salary.

Further, correlation findings show a negative relationship between collaborative network constraint and salary at time t2. The negative relationship suggests that scientists situated in constrained collaborative network structures earn lower salary. In constrained network structures, the relatively powerful collaborator may withhold professional recognition and rewards from the ego scientist. Lastly, introductions provided by collaborators is positively correlated to salary but negatively correlated to dollar amount of largest grant. Perhaps, introduction provided by collaborators represents a resource which may help the ego scientist earn higher salary but may not help in getting a large grant in terms of dollar amount. In other words, introduction provided by collaborators is not an all-purpose resource but one that is reward specific.

Third, correlation findings on the relationship between reward outcomes and satisfaction indicate that salary at t1 is positively correlated with both kinds of satisfaction at t2. Dollar amount of largest grant at t1 is positively correlated with satisfaction with reputation of department and institution at t2. Awards at t1 are positively correlated with both kinds of satisfaction at t2.

Fourth, further examination of the correlation table reveals the importance of several non-network control variables for two kinds of satisfaction. Number of courses taught or co taught is negatively correlated with both kinds of satisfaction. Further, scientists located in larger departments are more satisfied with reputation of department and institution. Negative correlation is found between women scientists and both kinds of satisfaction. Specifically, women scientists are less satisfied with rewards as well with the reputation of their department and institution compared to men. Assistant professors and associate professors are found to be less satisfied with rewards as well as less satisfied with the reputation of their department and institution than full professors. Among the fields, positive correlation is found between computer science and both kinds of satisfaction. In other words, computer scientists are found to be more satisfied than biologists. Earth and environmental scientists are found to be more satisfied with reputation of their department and institution as compared to biologists.

Finally, correlation findings indicate some initial support for three propositions proposed in chapter 3. For example, as expected collaborative network constraint is negatively correlated with superior collaborators. Although, this indicates initial empirical support for the first proposition *(P1),* multivariate analysis is needed to confirm support for this proposition. Next, correlation findings suggest that strong collaborative ties (by duration, frequency, and close friendships) are positively related to resources received from collaborative ties, thereby showing initial support for the second proposition *(P2).* Strong collaborative ties are also positively correlated with superior collaborators. This finding fails to support the third proposition *(P3).* Further, correlation findings suggest that scientists with a large number of superior collaborators receive greater amount of resources from their collaborative networks in the form of introductions and nominations for awards. This finding lends initial support to *P4*.

5.5. OLS regression findings

In the previous section, correlation findings among the focal variables were reported. As the level of confidence in causal inference from bivariate correlations is low, multivariate analysis is conducted in this section to understand the effects of collaborative networks at time t1 on satisfaction at time t2. Four OLS regression models are run in this section. First two regression models predicting average satisfaction with rewards at t2 are run without and with linear interpolation followed by two models predicting average satisfaction with reputation of department and institution at t2 also run without and with linear interpolation. All the four OLS regression models are run with sample weights.

The distribution of the dependent variables was considered when selecting an appropriate estimate method. The normality of residuals was also taken into account to make sure that the assumptions of OLS are not violated. The distribution of residuals indicated a reasonably normal distribution. Histograms for both dependent variables are shown below.

Fig 12. Histogram of average satisfaction with rewards

Fig 13. Histogram of average satisfaction with reputation of department and institution

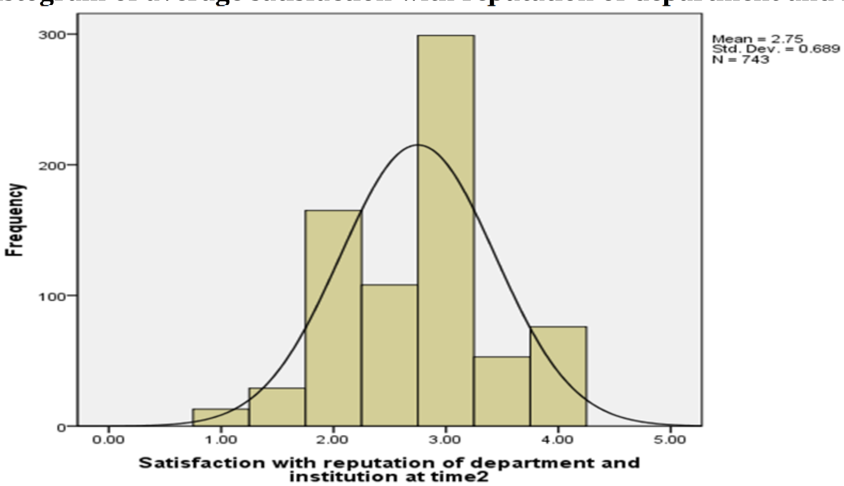


Fig 14. Residual plot for satisfaction with rewards

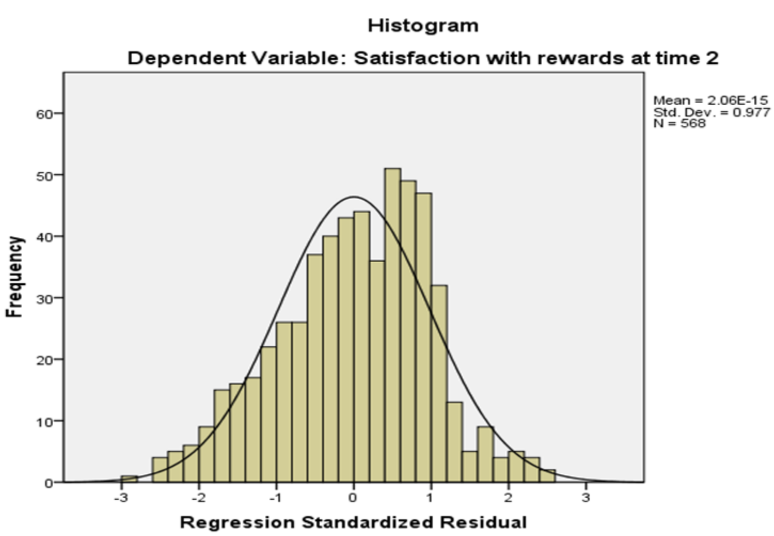
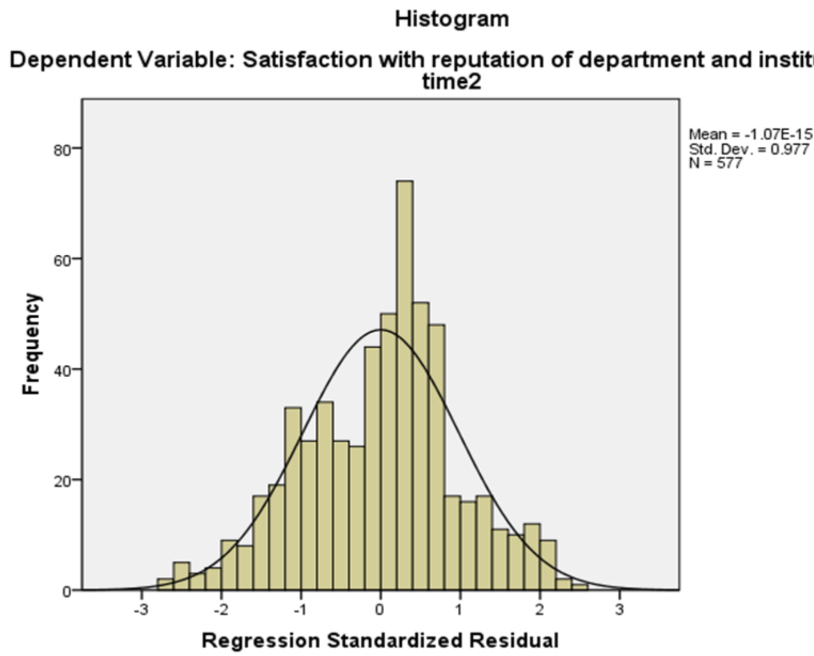


Fig 15. Residual plot for satisfaction with reputation of department and institution



5.5.1 OLS regression predicting satisfaction with rewards

Findings of the first two regression models predicting satisfaction with rewards run without and with linear interpolation are very similar. For example, in both regression models, collaborative network constraint is negatively related to satisfaction with rewards. Specifically, scientists situated in structurally constrained collaborative networks report a lower level of satisfaction with rewards. Structurally constrained scientists may have lower access to resources, and may be less likely to attain rewards and recognition, and hence may report a report a lower level of satisfaction with rewards. The structurally powerful collaborator may also be controlling, and even coercive in their interaction with the ego scientist. As a result, the ego scientist may perceive himself or herself to be socially less valued, and less legitimate, and therefore may report a lower level of satisfaction with rewards. This finding shows some initial support for H1.

Next, strong collaborative ties characterized by duration of collaborative interaction, and frequency of collaborative interaction are negatively related with satisfaction with rewards for both models predicting satisfaction with rewards run without and with linear interpolation. The negative sign suggests that scientists connected to a large number of strong collaborative ties may be likely to perceive over dependence on their strong ties, or a lack of sense of control over their work. Such perceptions are less likely to lead to perceived fulfillment of rewards. Another possible reason for the negative relationship between strong collaborative ties and satisfaction with rewards may be that strong collaborative ties are similar in terms of knowledge, and level of skills and expertise, and that similarity may limit the exposure of the ego scientist to diverse actors and diverse knowledge essential for greater professional recognition and rewards, thereby the scientist may report a lower level of satisfaction with rewards. This finding that strong collaborative ties characterized by duration of collaborative interaction, and frequency of collaborative interaction are negatively related with satisfaction with rewards shows some initial support for the negative direct effect of strong collaborative ties on satisfaction with rewards. Path analysis will be conducted later to confirm support for this finding. While, strong ties by duration and frequency are negatively related to satisfaction with rewards, close friendship with collaborators is positively related to satisfaction with rewards. Perhaps, collaborative exchange with close friends is likely to be reciprocal in the sense that close friends may be motivated to accord recognition to the scientist. Reciprocity is the key social mechanism through which scientists gain rewards and recognition in the scientific community. Hence, having a large number of close friends helps the scientists achieve rewards and recognition, and thereby leads to a higher level of satisfaction with rewards.

Further, scientists connected to a large number of senior collaborators report a higher level of satisfaction with rewards. This finding holds for both models run without and with linear interpolation. Senior collaborators may provide greater access to resources, legitimacy to the ego scientist, and validation to the ideas of the ego scientist. As a result, collaborative exchange with senior collaborators may result in rewards and recognition, and higher level of satisfaction with rewards. This finding shows some initial support for the positive direct effect of connections to superior collaborators on satisfaction with rewards. While, having a large number of senior collaborators enhances satisfaction with rewards, having a large number of collaborators who are better grant getters does not. Specifically, scientists connected to a large number of better grant getters report a lower level of satisfaction with rewards. The negative relationship may be explained from a social status perspective. Specifically, connections to higher status collaborators lower the status of the ego scientist. Lower status may lead to negative perceptions about oneself such as perceptions of incompetence or perceptions of not being able to reciprocate in return for the assistance received from higher status collaborators. Such negative perceptions may lead to lower levels of satisfaction. Regression findings on the relationship between resources received from collaborators and satisfaction with rewards indicates that nomination for awards is positively related to satisfaction with rewards in the model run without linear interpolation. Introductions provided by collaborators are not significant in any of the models.

Turning to the relationship between reward outcomes and satisfaction with rewards, OLS regression findings for both models predicting satisfaction with rewards run without and with linear interpolation suggest that salary is positively related to satisfaction with rewards. This means that scientists who earn higher salary report a higher level of satisfaction with rewards. However, the other reward outcome, dollar amount of largest grant is negatively related to satisfaction with rewards.

OLS findings on the relationship between non network and demographic determinants suggest that scientists who receive greater amount of resources from their departments report a higher level of satisfaction with rewards. Further, female scientists are less satisfied with rewards compared to their male counterparts. Assistant professors and associate professors are less satisfied with rewards compared to full professors. African American/black scientists are found to be more satisfied with rewards compared to white scientists. Physicists and computer scientists are more satisfied with rewards compared to biologists. These findings hold for both models predicting satisfaction with rewards run without and with linear interpolation.

5.5.2. OLS regression predicting satisfaction with reputation of department and institution

Findings for the two regression models predicting satisfaction with reputation of department and institution run without and with linear interpolation are very similar. For example, in both regression models, collaborative network constraint is negatively related to satisfaction with reputation of department and institution. The ego scientist may perceive himself or herself to be socially less valued, and less legitimate in a structurally constrained network as the relatively powerful collaborator may withhold resources and professional recognition from the ego scientist. When the ego scientist perceives to be socially less valued, he or she may be likely to view his or her department or institution in a negative light. As a result, the scientist may report a lower level of satisfaction with the reputation of department and institution. This finding shows some initial support for H1. Path analysis will be conducted in the later sections of this dissertation to confirm support for this finding.

Next, strong collaborative ties characterized by duration of collaborative interaction are negatively related with satisfaction with reputation of department and institution for both models run without and with linear interpolation. The negative sign may suggests that collaborative exchange with strong redundant collaborative ties limits the exposure of the ego scientist to get connected to actors in the disparate parts of the academic social system resulting in lower levels of professional recognition and reputation. As a result, the scientist reports a lower level of satisfaction with reputation of their department and institution. This finding shows some initial support for the negative direct effect of strong collaborative ties on satisfaction with reputation of department and institution. Path analysis will be conducted later to confirm support for this finding. Frequency of collaborative interaction, and close friendship with collaborators are unrelated to satisfaction with reputation of department and institution.

Further, scientists connected to a large number of better grant getters report a lower level of satisfaction with reputation of department and institution. This negative relationship may be explained from a social status perspective. Specifically, social status perspective argues that connections to higher status collaborators in terms of grant getting ability may lower the status of the ego scientist. Lower status may lead to negative perceptions about oneself and about one's department and institution, leading to lower levels of satisfaction with the reputation of department and institution. Regression findings on the relationship between resources received from collaborators and satisfaction with reputation of department and institution indicates that introductions provided by collaborators are positively related to satisfaction with reputation of department and institution, while nomination for awards is negatively related. Perhaps, introductions to other potential collaborators may indicate the ego scientist is perceived to be competent and socially valued. When the scientists are aware that they are socially valued, it is reasonable to expect that they view their department and institution in a positive light, thereby reporting a higher level of satisfaction with reputation of their department and institution. Nominations for awards provided by collaborators, on the other hand is negatively related to satisfaction with reputation of department and institution. Perhaps, nominations for awards represent a resource that positively contributes to fulfillment of one's own reward expectations but does not fulfill expectations about their departmental and institutional reputation.

Turning to the relationship between reward outcomes and satisfaction with reputation of department and institution, OLS regression findings for both models predicting satisfaction with reputation of department and institution run without and with linear interpolation suggest that salary is positively related to satisfaction with reputation of department and institution. This means that scientists who earn higher salary report a higher level of satisfaction with reputation of department and institution. However, dollar amount of largest grant is unrelated to satisfaction with reputation of department and institution. Awards received by scientists positively contribute to their satisfaction with reputation of department and institution.

OLS findings on the relationship between non network and demographic determinants suggest that scientists in larger departments report a higher level of satisfaction with reputation of department and institution. Further, Assistant professors and associate professors are less satisfied with reputation of their department and institution compared to full professors. African American/black scientists and Hispanic scientists are found to be more satisfied with reputation of department and institution compared to white scientists. Earth and environmental scientists and computer scientists are more satisfied with reputation of department and institution compared to biologists. These findings hold for both models predicting satisfaction with reputation of department and institution run without and with linear interpolation.

5.5.3. Summary of regression findings

In the previous section, OLS regressions findings on the effects of collaborative networks on two kinds of satisfaction namely satisfaction with rewards and satisfaction with reputation of department and institution were presented and discussed. In this section, a summary of regression findings for both kinds of satisfaction are discussed.

In summary, some of the collaborative network properties are found to be negative predictors of both kinds of satisfaction. For example, collaborative network constraint is negatively related to both kinds of satisfaction. Structurally constrained scientists may have lower access to resources, and may be less likely to attain rewards and professional recognition, and hence report a report a lower level of satisfaction. Additionally, scientists in a structurally constrained collaborative network perceives to be controlled by a relatively powerful collaborative, perceives to be less legitimate and so on. Such perceptions lead to negative evaluations about one’s ability to achieve rewards as well as negative perceptions of one’s department and institution. Next, scientists that have a large number of collaborators who are better grant getters report lower levels of satisfaction. In other words, having a large number of better grant getters is negatively related to both kinds of satisfaction. This negative relationship may be explained from a social status perspective. Specifically, social status perspective argues that connections to higher status collaborators in terms of grant getting ability may lower the status of the ego scientist. Lower status may lead to negative perceptions about oneself and about one's department and institution, leading to lower levels of satisfaction with rewards and lower levels of satisfaction with reputation of department and institution.

Resources received from collaborators in the form of nomination for awards positively predicts satisfaction with rewards but is negatively related to satisfaction with reputation of department and institution. Perhaps, nominations for awards represents a resource that positively contributes to fulfillment of one's own reward expectations but does not fulfill expectations about their departmental and institutional reputation. In other words, nominations for awards is not an all-purpose resource, rather it is satisfaction specific. Introductions to potential collaborators, on the other hand, positively predict satisfaction with reputation of department and institution, but is unrelated to satisfaction with rewards.

OLS regression findings for the relationship between rewards and satisfaction indicate that salary positively predicts both kinds of satisfaction. This means that scientists who earn higher salary report a higher level of satisfaction. However, the other reward outcome, dollar amount of largest grant is negatively related to satisfaction with rewards, and unrelated to satisfaction with reputation of department and institution.

Finally, regression findings on the relationship between non network and demographic control factors and satisfaction indicate that assistant and associate professors are less satisfied with both kinds of satisfaction compared to full professors. African American scientists are more satisfied with both kinds of satisfaction compared to whites. Computer scientists are more satisfied with both kinds of satisfaction compared to biologists.

TABLE X. CORRELATIONS

	1	2	3	4	5	6	7	8	9	10
1 Collaborative network constraint	1									
2 Number of strong collaborative ties by duration	-0.24***	1								
3 Number of strong collaborative ties by frequency	-0.12***	0.56***	1							
4 Number of strong collaborative ties by close friendship	-0.06***	0.41***	0.39***	1						
5 Number of senior collaborators	-0.12***	0.25***	0.11***	0.04***	1					
6 Number of collaborators who have a better grant getting capacity	-0.09***	0.28***	0.11***	0.10***	0.49***	1				
7 Number of collaborators who provide introductions	-0.14***	0.48***	0.39***	0.34***	0.18***	0.25***	1			
8 Number of collaborators who provide nominations	-0.14***	0.41***	0.26***	0.23***	0.15***	0.19***	0.43***	1		
9 Salary at time t1 (in 10000 dollars)	-0.01	0.13***	0.08***	-0.05***	-0.26***	-0.19***	0.10***	0.12***	1	
10 Salary at time t2 (in 10000 dollars)	-0.05***	0.18***	0.09***	-0.01	-0.20***	-0.20***	0.05***	0.13***	0.64***	1
11 Largest dollar amount of grants at time t1 (in 10000 dollars)	-0.07***	0.02	-0.00	-0.05***	0.004	-0.04**	-0.05***	0.02	0.14***	0.19***
12 Largest dollar amount of grants at time t2 (in 10000 dollars)	0.02	0.05***	0.05***	-0.04**	-0.02	-0.03**	-0.03**	0.05***	0.05***	0.09***
13 Sum of awards at time t1	-0.04**	0.12***	-0.00	-0.01	0.12***	-0.05***	0.07***	0.09***	0.05***	0.14***
14 Journal articles at time t1	-0.08***	0.34***	0.20***	0.16***	0.04**	-0.10***	0.12***	0.25***	0.16***	0.24***
15 Receipt of departmental resources	-0.06***	0.08***	0.14***	0.02	0.10***	0.04**	0.05***	0.01	-0.04**	0.01
16 Number of courses taught/co-taught at time t1	0.01	0.05***	0.00	0.04**	-0.06***	0.007	-0.04**	-0.02	-0.14***	-0.14***
17 Dept. faculty size	0.005	0.05***	0.03**	-0.01	-0.04**	-0.02	0.04**	0.13***	0.14***	0.14***
18 Female	0.05***	-0.01	-0.04**	0.01	0.13***	0.06***	-0.05***	-0.02	-0.07***	-0.08***
19 Assistant Professor	0.03**	-0.19***	-0.06***	-0.07***	0.43***	0.25***	-0.06***	-0.10***	-0.30***	-0.29***
20 Associate Professor	0.03**	-0.03**	-0.04**	0.01	0.10***	0.01	-0.03**	0.00	-0.23***	-0.21***
21 Physics	0.08***	0.06***	0.16***	0.01	-0.01	-0.01	-0.01	0.14***	-0.01	-0.01
22 Chemistry	-0.04**	-0.16***	-0.23***	-0.14***	0.008	0.06***	-0.06***	-0.02	-0.03**	-0.01
23 EAS	-0.05***	0.15***	0.05***	0.14***	0.005	0.003	0.05***	0.04**	-0.05***	-0.03**
24 CS	0.05***	0.07***	0.14***	0.02	0.01	0.02	0.09***	-0.01	0.14***	0.11***
25 EE	-0.06***	-0.006	0.02	-0.07***	0.007	-0.005	0.03**	-0.06***	0.10***	0.17***
26 South or southeast Asian	0.06***	-0.005	0.03**	-0.02	0.10***	0.07***	-0.008	-0.06***	0.003	0.01
27 Black/African American, not of Hispanic origin	-0.13***	-0.009	0.00	0.06***	-0.009	0.01	0.04**	-0.01	-0.05***	-0.01
28 Hispanic	-0.008	-0.02	-0.02	-0.07***	-0.01	-0.02	-0.01	0.01	-0.08***	-0.003
29 Satisfaction with rewards at time 2	-0.07***	-0.01	-0.04**	0.02	-0.03**	-0.09***	0.02	0.00	0.24***	0.26***
30 Satisfaction with reputation of department and institution at time t2	-0.09***	-0.01	0.00	-0.03**	-0.11***	-0.17***	0.02	-0.004	0.23***	0.19***
31 Satisfaction with rewards at t1	-0.04***	0.04**	0.02	0.03**	0.04**	-0.07***	0.00	0.01	0.29***	0.30***
32 Satisfaction with reputation at t1	-0.02	0.01	0.03**	-0.02	-0.10***	-0.17***	-0.00	0.02	0.23***	0.23***

		11	12	13	14	15	16	17	18	19	20
11	Largest dollar amount of grants at time t1 (in 10000 dollars)	1									
12	Largest dollar amount of grants at time t2 (in 10000 dollars)	0.04**	1								
13	Sum of awards at time t1	0.03**	0.09***	1							
14	Journal articles at time t1	0.09***	0.11***	0.12***	1						
15	Receipt of departmental resources	0.02	-0.03**	0.04**	-0.07***	1					
16	Number of courses taught/co-taught at time t1	-0.08***	-0.001	-0.05***	-0.09***	0.001	1				
17	Dept. faculty size	0.12***	0.01	0.09***	0.03**	-0.09***	-0.07***	1			
18	Female	-0.03**	0.03**	0.02	-0.06***	0.03**	-0.07***	-0.03**	1		
19	Assistant Professor	-0.07***	-0.03**	-0.03**	-0.14***	0.09***	-0.13***	-0.05***	0.15***	1	
20	Associate Professor	-0.07***	-0.03**	0.05***	-0.08***	0.005	0.22***	-0.06***	0.04**	-0.29***	1
21	Physics	0.18***	-0.04**	-0.09***	0.15***	-0.001	-0.07***	0.10***	-0.08***	-0.06***	-0.11***
22	Chemistry	-0.05***	0.05***	-0.04**	0.11***	-0.04**	-0.06***	-0.13***	-0.02	0.04**	-0.05***
23	EAS	-0.03**	-0.05***	0.005	-0.04**	0.04**	0.08***	-0.18***	0.02	-0.01	0.01
24	CS	-0.02	0.03**	0.03**	-0.14***	0.02	0.02	0.15***	-0.03**	0.01	0.001
25	EE	-0.04**	-0.01	0.05***	0.02	0.01	0.12***	-0.04**	-0.09***	-0.06***	0.12***
26	South or southeast Asian	-0.002	-0.009	-0.01	0.02	-0.07***	0.05***	-0.000	-0.001	0.03**	0.04**
27	Black/African American, not of Hispanic origin	-0.02	-0.03**	-0.03**	-0.06***	-0.004	0.07***	-0.04**	0.01	-0.007	0.06***
28	Hispanic	-0.02	-0.009	0.07***	-0.07***	0.02	0.05***	0.01	0.04**	0.02	0.05***
29	Satisfaction with rewards at time 2	0.007	-0.03**	0.02	-0.004	0.07***	-0.05***	0.02	-0.06***	-0.03**	-0.10***
30	Satisfaction with reputation of department and institution at time2	0.06***	-0.002	0.08***	-0.003	0.008	-0.03**	0.10***	-0.05***	-0.11***	-0.06***
31	Satisfaction with rewards at t1	0.07***	0.07***	0.11***	0.02	0.11***	-0.14***	0.09***	-0.03**	0.08***	-0.16***
32	Satisfaction with reputation at t1	0.05***	0.04**	0.07***	0.04**	0.04**	-0.06***	0.17***	0.01	-0.07***	-0.09***

		21	22	23	24	25	26	27	28	29	30	31
21	Physics	1										
22	Chemistry	-0.22***	1									
23	EAS	-0.19***	-0.18***	1								
24	CS	-0.18***	-0.18***	-0.15***	1							
25	EE	-0.18***	-0.18***	-0.15***	-0.15***	1						
26	South or southeast Asian	0.06***	-0.04**	-0.06***	0.05***	0.10***	1					
27	Black/African American, not of Hispanic	-0.01	0.02	-0.03**	0.01	0.02	-0.02	1				
28	Hispanic	-0.07***	-0.01	-0.04**	-0.01	0.07***	-0.03**	-0.01	1			
29	Satisfaction with rewards at time 2	-0.06***	-0.02	0.02	0.11***	-0.01	-0.01	0.05***	-0.009	1		
30	Satisfaction with reputation at time2	-0.02	-0.04**	0.06***	0.05***	0.004	0.005	0.02	0.03**	0.43***	1	
31	Satisfaction with rewards at t1	-0.05***	-0.04**	0.009	0.10***	0.01	-0.04**	0.01	0.02	0.57***	0.29***	1
32	Satisfaction with reputation at t1	-0.03**	-0.03**	0.06***	0.01	0.007	0.04**	-0.001	0.05***	0.28***	0.61***	0.39***

TABLE XI. OLS REGRESSION PREDICTING AVERAGE SATISFACTION WITH REWARDS AT T2

	with weights									
	without linear interpolation					with linear interpolation				
DV: Satisfaction with rewards at t2	B	Std. Error	Beta	t	Sig.	B	Std. Error	Beta	t	Sig.
(Constant)	2.454	0.077		31.865	0.000	2.372	0.063		37.393	0.000
Collaborative network constraint	-0.127	0.048	-0.047	-2.671	0.008	-0.162	0.039	-0.061	-4.139	0.000
Number of strong collaborative ties by duration	-0.022	0.007	-0.079	-3.082	0.002	-0.021	0.006	-0.072	-3.293	0.001
Number of strong collaborative ties by frequency	-0.034	0.009	-0.086	-3.934	0.000	-0.039	0.008	-0.09	-4.944	0.000
Number of strong collaborative ties by close friendship	0.026	0.008	0.066	3.324	0.001	0.036	0.007	0.084	5.13	0.000
Number of senior collaborators	0.043	0.008	0.116	5.064	0.000	0.035	0.008	0.088	4.581	0.000
Number of collaborators who have a better grant getting capacity	-0.025	0.009	-0.06	-2.936	0.003	-0.033	0.008	-0.074	-4.262	0.000
Number of collaborators who provide introductions	0.011	0.008	0.029	1.397	0.163	0.007	0.007	0.018	1.035	0.3
Number of collaborators who provide nominations	-0.021	0.012	-0.036	-1.819	0.069	-0.005	0.01	-0.008	-0.473	0.636
Salary at time t1 (in 10000 dollars)	0.036	0.004	0.2	9.973	0.000	0.041	0.003	0.221	13.15	0.000
Largest dollar amount of grants at time t1 (in 10000 dollars)	0.000	0.000	-0.073	-4.297	0.000	0.000	0.000	-0.03	-2.047	0.041
Awards at time t1	-0.024	0.015	-0.027	-1.538	0.124	0.005	0.013	0.006	0.416	0.678
Number of journal articles at time t1	-0.01	0.008	-0.025	-1.295	0.195	-0.004	0.006	-0.01	-0.588	0.557
Receipt of departmental resources	0.036	0.008	0.071	4.196	0.000	0.046	0.007	0.093	6.409	0.000
Number of courses taught/co-taught in past academic year at time t1	0.003	0.01	0.006	0.315	0.753	-0.012	0.009	-0.021	-1.38	0.168
Department faculty size	0.001	0.000	0.028	1.569	0.117	0.000	0.000	-0.006	-0.389	0.697
Female	-0.133	0.031	-0.074	-4.319	0.000	-0.114	0.026	-0.063	-4.344	0.000
Assistant Professor	-0.143	0.037	-0.092	-3.818	0.000	-0.05	0.031	-0.031	-1.606	0.108
Associate Professor	-0.19	0.031	-0.127	-6.109	0.000	-0.124	0.026	-0.082	-4.83	0.000
Physics	-0.07	0.037	-0.041	-1.883	0.06	-0.057	0.031	-0.034	-1.831	0.067
Chemistry	-0.063	0.037	-0.037	-1.696	0.09	-0.042	0.031	-0.025	-1.371	0.171
EAS	0.045	0.038	0.025	1.178	0.239	0.056	0.033	0.029	1.716	0.086
CS	0.145	0.04	0.075	3.667	0.000	0.162	0.033	0.084	4.869	0.000
EE	-0.113	0.041	-0.056	-2.746	0.006	-0.053	0.034	-0.028	-1.589	0.112
South or Southeast Asian	-0.013	0.06	-0.004	-0.216	0.829	0.023	0.05	0.006	0.45	0.653
Black/African American, not of Hispanic origin	0.421	0.113	0.063	3.724	0.000	0.394	0.089	0.063	4.418	0.000
Hispanic	0.135	0.066	0.034	2.034	0.042	0.085	0.059	0.02	1.424	0.155
N			568					765		
Model significance			***					***		
R square			0.11					0.1		

TABLE XII. OLS REGRESSION PREDICTING AVERAGE SATISFACTION WITH REPUTATION OF DEPARTMENT AND INSTITUTION AT T2

	with weights									
	without imputation					with imputation				
DV: Satisfaction with reputation of dept. and inst at t2	B	Std error	beta	t	Sig	B	Std error	beta	t	Sig
(Constant)	2.826	.075		37.450	.000	2.688	.064		42.028	.000
Collaborative network constraint	-.276	.047	-.102	-5.826	.000	-.267	.040	-.100	-6.759	.000
Number of strong collaborative ties by duration	-.025	.007	-.091	-3.609	.000	-.023	.006	-.077	-3.542	.000
Number of strong collaborative ties by frequency	.005	.009	.014	.631	.528	.006	.008	.013	.704	.482
Number of strong collaborative ties by close friendship	-.011	.008	-.028	-1.418	.156	-.004	.007	-.008	-.516	.606
Number of senior collaborators	.010	.008	.028	1.225	.221	.011	.008	.027	1.419	.156
Number of collaborators who have a better grant getting capacity	-.039	.008	-.094	-4.631	.000	-.050	.008	-.112	-6.444	.000
Number of collaborators who provide introductions	.021	.008	.055	2.708	.007	.017	.007	.042	2.415	.016
Number of collaborators who provide nominations	-.034	.012	-.056	-2.916	.004	-.017	.010	-.027	-1.631	.103
Salary at time t1 (in 10000 dollars)	.021	.004	.119	6.016	.000	.032	.003	.172	10.224	.000
Largest dollar amount of grants at time t1 (in 10000 dollars)	.000	.000	-.018	-1.097	.273	.000	.000	.013	.888	.375
Awards at time t1	.052	.015	.059	3.444	.001	.054	.013	.060	4.095	.000
Number of journal articles at time t1	-.004	.007	-.010	-.489	.625	-.016	.006	-.041	-2.467	.014
Receipt of departmental resources	.008	.008	.017	1.020	.308	.010	.007	.021	1.459	.145
Number of courses taught/co-taught in past academic year at time t1	-.021	.010	-.037	-2.094	.036	-.008	.009	-.015	-.966	.334
Department faculty size	.003	.000	.119	6.843	.000	.002	.000	.090	5.999	.000
Female	-.030	.030	-.017	-.995	.320	-.047	.026	-.026	-1.792	.073
Assistant Professor	-.201	.037	-.130	-5.441	.000	-.115	.031	-.071	-3.647	.000
Associate Professor	-.150	.031	-.101	-4.897	.000	-.070	.026	-.046	-2.696	.007
Physics	-.019	.036	-.011	-.513	.608	.019	.031	.011	.598	.550
Chemistry	-.072	.037	-.043	-1.985	.047	.013	.031	.007	.406	.684
EAS	.217	.037	.120	5.818	.000	.209	.033	.109	6.333	.000
CS	.081	.039	.042	2.066	.039	.057	.034	.030	1.705	.088
EE	-.031	.040	-.016	-.763	.446	-.006	.034	-.003	-.188	.851
South or Southeast Asian	.042	.057	.012	.725	.469	.104	.050	.030	2.064	.039
Black/African American, not of Hispanic origin	.280	.112	.042	2.500	.012	.243	.090	.039	2.709	.007
Hispanic	.211	.066	.054	3.216	.001	.224	.060	.054	3.741	.000
N			577					765		
Model significance			***					***		
R square			0.11					0.1		

5.6. Structural equation modeling

In the previous sections, correlation and OLS regression findings on the relationship between collaborative networks and satisfaction were presented and discussed. In this section, findings from structural equation modeling are presented and discussed to understand in depth the direct and indirect effects of collaborative networks on both kinds of satisfaction.

The objective of structural equation modeling is to provide a quantitative test of a theoretical model hypothesized by the researcher. There are two major types of variables in structural equation modeling: observed (indicator) variables, and latent (construct) variables. Latent variables are not directly observable or measured, rather they are observed or measured indirectly, and hence they are inferred constructs based on what observed variables we select to define the latent variable. In this study, for example, strong collaborative ties is a latent variable which is measured indirectly through three indicator variables—duration of collaborative interaction, frequency of collaborative interaction, and close friendships. Any latent variable that is predicted by other latent variable in a structural equation model is a latent dependent variable. A latent dependent variable must have at least one arrow leading to it from another latent variable. In this study, for example, satisfaction with rewards at t2 is a latent dependent variable because it has arrows leading to it from other variables. A latent variable that does not have an arrow leading to it in a structural equation model is known as a latent independent variable. For example, strong collaborative ties is a latent independent variable because it leads to satisfaction with rewards at t2, as well as to other latent dependent variables such as superior collaborators, and resource received from collaborators.

Theoretical models can be tested in SEM that hypothesizes how sets of indicator variables define constructs or latent variables and how these constructs are related to each other. For example, in the context of this research, three variables namely duration of collaborative interaction, frequency of collaborative interaction, and close friendships define strong collaborative ties, a latent construct which is then hypothesized to be related to satisfaction among academic scientists. The overall goal of structural equation modeling is to determine the extent to which the theoretical model is supported by data. SEM tests theoretical models using the scientific method of hypotheses testing to advance our understanding of the complex relationships between constructs. Two approaches that make up structural equation modeling are: 1) confirmatory factor analysis, 2) path analysis.

Confirmatory factor analysis

A confirmatory factor model is specified to define the relationships between latent and indicator variables based on theoretical considerations. The indicator variables are enclosed in boxes or rectangles, and the factors or latent variables are enclosed by circles or ellipses. Latent variables are not directly observable or measured, rather they are observed or measured indirectly, and hence are inferred constructs based on variables selected to define the latent variable. Conceptually, a factor or latent variable represents the common variance among a set of observed variables. One needs to select two or three observed variable to measure a latent variable to show evidence of reliability and validity. In the structural equation model used in this study, three latent independent variables—strong collaborative ties, superior collaborative ties, and resources received by collaborators are used to predict two kinds of satisfaction. The latent dependent variables --- satisfaction with rewards is measured by three observed variables namely, satisfaction with salary, satisfaction with reward system at the institution, and satisfaction with department's reward allocation for productivity and satisfaction with reputation of department and institution is measured by two observed variables namely satisfaction with the reputation of the department, and satisfaction with the reputation of the institution.

Path analysis

Path analysis is the logical extension of multiple regression models. In multiple regression analysis, a dependent variable is regressed in a single analysis on all of the independent variables. In path analysis, one or more multiple regression is performed depending on the variables and the relationships specified in the path model. Specifically, path models comprise a number of independent and dependent variables and any number of equations.

Path analysis estimates direct and indirect effects for each variable. Lines directed from one variable to another denote direct effect. Specifically, direct effects are effects that go directly from one variable to another. For example, in this study, strong collaborative ties at t1 have a direct influence on satisfaction with rewards at t2, meaning that strong collaborative ties at t1 may influence an increase (or decrease) in satisfaction with rewards at t2 of academic scientists. Indirect effect is the influence of one variable on another through one or more mediating variables (Schumacker and Lomax, 2004; Lacobucci, 2008). For example, strong ties have direct effect on satisfaction as well as an indirect effect on satisfaction with rewards through mediating variables such as salary at t2 and dollar amount of largest grant at t2. Indirect effect tells us how much of a given effect occurs because the independent variable leads to changes in the intervening variable which in turn leads to change in the outcome or dependent variable. Indirect effect is the amount of change in the outcome variable that comes indirectly (through intervening variables) by a one unit change in the independent variable. The total effect is the summation of direct and indirect effects.

5.6.1. Structural equation model predicting satisfaction with rewards at time t2 (without regression imputation)

This following section presents the findings of SEM model wherein rewards and recognition at time t2 mediate the relationship between four collaborative network properties and satisfaction with rewards at time t2. This model is run with weights and without imputing the missing data. Findings for this model are presented in the following format. First, confirmatory factor analysis findings are presented followed by model fit indices. Next, path analysis findings (total, direct, and indirect effects) are presented and discussed.

5.6.2. Confirmatory factor analysis: SEM model 1 predicting satisfaction with rewards at time t2 (without regression imputation)

Among the indicator variables that define strong collaborative ties, duration of collaborative interaction (collabduration_sum) has the highest standardized factor loading of 0.809 and corresponding squared multiple correlations (R square) of 65%. This means that duration of collaborative interaction explains a respectable portion of the variance in strong ties. The other two indicator variables that define strong ties are frequency of collaborative interaction and close friendship with collaborators, both of which have the standardized factor loading of

0.662, and 0.477 respectively. Frequency of collaborative interaction and close friendship with collaborators explain around 44% and 23% of the variance in strong ties.

Two indicator variables define the latent variable superior ties are number of senior collaborators (collabsenior_sum) and number of better grant getters (collabgrant_sum). The standardized factor loadings of number of senior collaborators, and better grant getters are 0.77, and 0.62 respectively with corresponding squared multiple correlations (R square) of 59% and 38% respectively.

Two indicators variables namely number of collaborators who provide introductions (collabintro_sum) and number of collaborators who provide nomination for awards (collabnom_sum) define the latent variable, resources received from collaborators. The standardized factor loadings of number of collaborators who provide introductions and number of collaborators who provide nominations for awards are 0.759, and 0.584 with corresponding squared multiple correlations (R square) of 58% and 34% respectively.

For this model, the three indicator variables that define the dependent latent variable—satisfaction with rewards at time 2, workSatNew_r7 (faculty reward system at the institution) has the highest standardized factor loading of 0.912 and corresponding squared multiple correlations (R square) of 83%. This means that workSatNew_r7 explains a respectable portion of the variance in satisfaction with rewards at time 2. The other two indicator variables that define satisfaction with rewards are WorkSatNew_r6 (department's allocation of rewards for productivity) and WorkSatNew_r8 (salary), both of which have the standardized factor loading of 0.826, and 0.67 respectively. WorkSatNew_r6 and WorkSatNew_r8 explain around 68% and 48% of the variance in satisfaction with rewards at time t2 respectively.

TABLE XIII. CONFIRMATORY FACTOR ANALYSIS—SATISFACTION WITH REWARDS WITHOUT IMPUTATION

			Estimate	Std. Est.	S.E.	C.R.	P	R square
collabnom_sum	<---	Resources	1	0.584				0.341
collabintro_sum	<---	Resources	2.118	0.759	0.081	26	***	0.576
WorkSatNew_r6	<---	Satisfaction with rewards at t2	1	0.826				0.685
WorkSatNew_r7	<---	Satisfaction with rewards at t2	1.12	0.912	0.022	50	***	0.831
WorkSatNew_r8	<---	Satisfaction with rewards at t2	0.813	0.67	0.02	41	***	0.482
collabfriend_sum	<---	Strong ties	1	0.477				0.228
collabduration_sum	<---	Strong ties	2.399	0.809	0.103	23	***	0.655
collabfreq_sum	<---	Strong ties	1.377	0.662	0.056	25	***	0.438
collabgrant_sum	<---	Superior ties	1	0.62				0.384
collabsenior_sum	<---	Superior ties	1.424	0.77	0.046	31	***	0.592

5.6.3. Assessing model fit: SEM model predicting satisfaction with rewards at time t2 (without regression imputation)

An important result of any structural equation model is the fit of the specified model. If the fit of the specified model is good, then the model is supported by the sample data. There are a wide variety of model fit indices available to SEM researchers such as chi square statistic, RMSEA, and CFI. The chi square $\chi 2$ statistic, technically a measure of badness of fit because the higher its value the worse the model corresponds to the sample data (Schumacker and Lomax, 2004). Chi Square very readily reaches significance level with large sample sizes even when all other indices indicate a good fit. When the chi square statistic is significant, it indicates that the model is rejected. However, several researchers have challenged the use of chi square to evaluate structural equation models with sample sizes more than 500 (Kline, 2005). Therefore it is important to view chi square statistic in context of other model fit indices such as RMSEA and CFI.

The root mean square error of approximation (RMSEA) is generally regarded as one of the most informative fit indices and shows how well the model fits the sample data. Values less than 0.05 are indicative of good fit (Schumacker and Lomax, 2004). Findings from this model suggest that RMSEA is 0.04, which indicates a good fit. Another fit index, comparative fit index (CFI) assesses the relative improvement in the fit of the model compared with a baseline model (Kline, 2005). CFI values equal or greater than 0.9 indicate a good fit. Findings from this model suggest that CFI is 0.91, which indicates a good fit.

5.6.4. Direct and indirect effects: SEM model predicting satisfaction with rewards at time t2 (without regression imputation)

Path analysis showed several significant direct effects. The direct effect of strong collaborative ties on resources received from collaborators is positive and significant (std. est. =0.806; p value=0.01). This suggests that scientists that have a large number of strong collaborative ties receive greater amount of resources from their collaborators *(P2)*. Next, path analysis findings showed reverse support for *P3*. Specifically, a negative relationship was proposed between strong collaborative ties and superior collaborators. However, path analysis finding showed that the direct effect of strong collaborative ties on superior collaborators is positive and significant (std. est. =0.486; p value=0.01).). One expected that since strong ties link actors of similar attributes in terms of status, it would be negatively related to the number of superior collaborators as superior collaborators are of higher status compared to the ego scientist. The positive sign suggests that academic scientists are more likely to be strongly tied to superior collaborators. Further, as expected, the direct effect of collaborative network constraint on number of superior collaborators is negative and significant *(P1)*. Specifically, scientists with higher constraint in their collaborative network have fewer superior collaborators in their network. Said in another way, scientists in constrained collaborative network are less likely to be connected to higher status collaborators in terms of seniority and grant getting ability.

Next, among the direct effects between network factors and satisfaction with rewards at t2, path analysis findings showed a negative and significant direct effect between collaborative network constraint at t1 and satisfaction with rewards at t2 (std. est. =-0.091; p value=0.01). The negative direct effect of collaborative network constraint on satisfaction with rewards suggests that academic scientists located in structurally constrained network perceive being controlled by a relatively powerful collaborator, and form negative perceptions about their capability of fulfilling their reward expectations. Specifically, in collaborative exchange with a relatively powerful collaborator, the less powerful ego scientist may not be able to access and control resources, and may perceive himself or herself to be socially less valued, and less legitimate, and therefore reports a lower satisfaction with rewards. Previous research has also found actors located in structurally disadvantageous locations report lower levels of satisfaction (Dean and Brass, 1985; Ibarra and Andrews, 1993; Rice and Mitchell, 1973; Settoon et al, 1996).

Path analysis findings also showed a negative and significant direct effect between strong collaborative ties at t1 and satisfaction with rewards at t2 (std. est. = -0.389; p value=0.01). The negative sign suggests that the presence of a large number of strong collaborative ties at t1 lowers satisfaction with rewards among academic scientists at t2. Perhaps the presence of a large number of strong collaborative ties creates perceptions of over dependence, incompetence, or lack of sense of control over ones work. Such perceptions are likely to lead to lower levels of satisfaction with rewards.

Further, the direct effect of connections to superior collaborators at t1 on satisfaction with rewards at t2 is positive and significant (std. est. = 0.246; p value=0.01). This finding suggests that academic scientists that are connected to a large number of superior collaborators perceive being socially valued, and legitimate, and hence form positive evaluations of their capability of fulfilling their reward expectations. Path analysis findings also showed a positive and significant direct effect of resources received from collaborators at t1 on satisfaction with rewards at t2 (std. est. = 0.166; p value=0.02). This positive direct effect suggests that receiving greater amount of resources from collaborators enhances self-esteem of academic scientists, and leads to positive evaluation of one's ability to achieve rewards and professional recognition. The academic scientist is aware that he or she is receiving resources from their collaborators, and as a result perceives being valued, and reports a higher level of satisfaction with rewards.

Path analysis findings also showed several significant direct effects between networks and rewards. For example, the direct effect of collaborative network constraint at t1 on salary at t2 is negative and significant (std. est. = -0.046; p value=0.02). This negative effect suggests that academic scientists located in structurally constrained collaborative networks earn lower salary at t2. Said in another way, collaborative exchange with a relatively powerful collaborator results in lower salary at t2. Another negative and significant direct effect is found between connections to superior collaborative ties at t1 and reward outcomes (salary and dollar amount of largest grant) at t2. This suggests that scientists who are connected to a large number of superior collaborators in terms of seniority and grant getting ability earn lower salary at t2 as well as receive smaller grants in terms of dollar amounts. Specifically, connections to large number of superior collaborators in terms of seniority and grant getting ability at t1 tend to reduce both reward outcomes at t2. Perhaps, this may be explained from a social status perspective. Specifically, connections to higher status collaborators lower the status of the ego scientist. Ego scientists of lower status may be less likely to access and control resources essential to achieve rewards and professional recognition.

Several positive and significant direct effects were also found between networks and rewards. For example, the direct effect of being connected to a large number of strong collaborative ties on both reward outcomes (salary and dollar amount of largest grant) is positive and significant. Specifically, academic scientists connected to a large number of strong collaborative ties at t1 achieve higher levels of rewards at t2. When scientists engage in collaborative exchange with strong ties, they offer their knowledge to their strong collaborative ties and in turn receive greater levels of rewards because strong collaborative ties are reciprocal in nature. Another positive and significant direct effect is found between resources received from collaborators at t1 and salary at t2. This finding means that academic scientists who receive greater amount of resources from their collaborators at t1 receive higher salary at t2.

Turning to the path analysis findings on the direct effects between rewards and satisfaction indicate that salary has a positive and significant direct effect on satisfaction with rewards at t2. This finding suggests that scientists who earn higher salary report a higher a higher level of satisfaction with rewards. Said in another way, higher salary leads to fulfillment of reward expectations resulting in higher levels of satisfaction with rewards. However, the other reward outcome—dollar amount of largest grant has a negative and significant effect on satisfaction with rewards. Perhaps, receiving large grants from external agencies may not result in fulfillment of reward expectations.

Among the relationships between non network and demographic control variables and satisfaction with rewards, the findings suggest that scientists who are located in department with large number of faculty report lower satisfaction with rewards. Perhaps, in large departments, there is greater competition to secure rewards, and scientists get lower level of rewards than they expect, resulting in a lower level of satisfaction with rewards. Further, scientists who publish more report a higher level of satisfaction with rewards. Scientists who receive greater amount of resources from their department report a higher level of satisfaction with rewards. Further, findings suggest that assistant professors and associate professors are less satisfied with rewards compared to full professors. Women scientists are less satisfied with rewards compared to men. Physicists, chemists, and electrical engineers are less satisfied with rewards compared to biologists.

Path analysis also showed several indirect effects. Indirect effects occur when the relationship between two variables is mediated by one or more variable. First, the indirect effect of collaborative network constraint at t1 on satisfaction with rewards at t2 is negative and significant (std. est. = -0.026; p value=0.01), supporting (H1). This means that for every one unit increase in constraint, a decrease of -0.026 unit of satisfaction with rewards is predicted through the effects of constraint on the intervening variables (salary at t2, dollar amount of largest grant at t2 and superior ties at t1). The negative indirect effect indicates that collaborative network constraint leads to changes in the intervening variables, which in turn lead to change in satisfaction with rewards, and this change is negative and significant. Note that the total and direct effect of collaborative network constraint on satisfaction with rewards is also negative and significant which suggests that there is little evidence for complete mediation of the intervening variables. If the direct effect is not significant, then there is evidence for complete mediation i.e. all the variance in the dependent variable explained by the independent variable, is mediated through intervening variables (lacobucci, 2008). The indirect effect of constraint can also be calculated by adding the product of indirect paths from constraint to satisfaction (see table below).

TABLE XIV. COMPUTING STANDARDIZED ESTIMATES OF THE INDIRECT EFFECTS OF COLLABORATIVE NETWORK CONSTRAINT ON SATISFACTION WITH REWARDS WITHOUT IMPUTATION

Indirect effect of constraint on satisfaction with rewards										
Constraint-->Superior ties-->satisfaction with rewards	=	-0.095	*	0.246					=	-0.02337
Constraint-->Superior ties-->salary-->satisfaction with rewards	=	-0.095	*	-0.439	*	0.181			=	0.007548605
Constraint-->Superior ties-->grant large-->satisfaction with rewards	=	-0.095	*	-0.117	*	-0.056			=	-0.00062244
Constraint-->salary-->satisfaction with rewards	=	-0.046	*	0.181					=	-0.008326
Constraint-->grant large-->satisfaction with rewards	=	0.015	*	-0.056					=	-0.00084
Constraint-->Superior ties-->resources-->salary-->satisfaction with rewards	=	-0.095	*	0.005	*	0.137	*	0.181	=	-1.18E-05
Constraint-->Superior ties-->resources-->grant large-->satisfaction with rewards	=	-0.095	*	0.005	*	-0.074	*	-0.056	=	-1.97E-06
Constraint-->Superior ties-->resources-->satisfaction with rewards	=	-0.095	*	0.005	*	0.166	*		=	-0.00007885
Adding all the indirect path coefficients									=	-2.57E-02

Next, the indirect effect of strong collaborative ties on satisfaction with rewards is found to be positive and significant (std. est. = 0.264; p value= 0.01), supporting (H2a). This means that for every one unit increase in strong collaborative ties, an increase of 0.264 unit of satisfaction with rewards is predicted through the effects of strong collaborative ties on the intervening variables (salary at t2, dollar amount of largest grant at t2, superior ties at t1, and resources received at t1). The positive indirect effect tells us that strong ties leads to changes in the intervening variables, which in turn leads to change in satisfaction with rewards and this change is positive and significant. Although the indirect effect of strong collaborative ties on satisfaction with rewards is positive and significant, there is little evidence for complete mediation of the intervening variables because the direct effect of and total effect of strong collaborative ties on satisfaction with rewards is negative and significant (Lacobucci, 2008). The indirect effect of strong ties on satisfaction with rewards is computed the in table below. The negative direct effect and positive indirect effect of strong collaborative ties on satisfaction with rewards may suggest that it is through the effects of rewards and recognition, and other intervening network variables that strong ties are able to fulfill ego scientist’s reward expectations. The indirect effect of strong ties on satisfaction with rewards is computed the in table below.

TABLE XV. COMPUTING STANDARDIZED ESTIMATES OF THE INDIRECT EFFECTS OF STRONG COLLABORATIVE TIES ON SATISFACTION WITH REWARDS WITHOUT IMPUTATION

Indirect effects of strong ties on satisfaction									
Strong ties-->superior ties-->satisfaction with rewards	0.486	*	0.246					=	0.119556
Strong ties-->superior ties-->salary-->satisfaction with rewards	0.486	*	-0.439	*	0.181			=	-0.0386171
Strong ties-->superior ties-->grant large-->satisfaction with rewards	0.486	*	-0.117	*	-0.056			=	0.0031843
Strong ties-->superior ties-->resources-->satisfaction with rewards	0.486	*	0.005	*	0.166			=	0.0004034
Strong ties-->superior ties-->resources-->salary-->satisfaction with rewards	0.486	*	0.005	*	0.137	*	0.181	=	6.03E-05
Strong ties-->superior ties-->resources-->grant large-->satisfaction with rewards	0.486	*	0.005	*	-0.074	*	-0.056	=	1.01E-05
Strong ties-->resources-->satisfaction with rewards	0.806	*	0.166					=	0.133796
Strong ties-->resources-->salary-->satisfaction with rewards	0.806	*	0.137	*	0.181	*		=	0.0199864
Strong ties-->resources-->grant large-->satisfaction with rewards	0.806	*	-0.074	*	-0.056	*		=	0.0033401
Strong ties-->salary-->satisfaction with rewards	0.171	*	0.181					=	0.030951
Strong ties-->grant large-->satisfaction with rewards	0.166	*	-0.056					=	-0.009296
	Adding all the indirect path coefficients (last column)							=	2.63E-01

Further, the indirect effect of connections to superior collaborators at t1 on satisfaction with rewards at t2 is negative and significant (std. est. = -0.072; p value= 0.01), supporting (H3b). This means that for every one unit increase in the number of superior collaborators, a decrease of -0.072 unit of satisfaction with rewards is predicted through the effects of superior collaborators on the intervening variables (salary at t2, dollar amount of largest grant at t2 and resources received at t1). The negative indirect effect indicates that connections to superior collaborators leads to changes in the intervening variables, which in turn lead to change in satisfaction with rewards, and this change is negative and significant. Scientists connected to a large number of superior collaborators are not able to convert those connections to rewards, and in turn report a lower level of satisfaction with rewards. Note that the total and direct effect of collaborative network constraint on satisfaction with rewards is positive and significant which suggests that there is little evidence for complete mediation of the intervening variables. The positive direct effect and negative indirect effect of connections to superior collaborators on satisfaction with rewards at t2 suggests that, the validation and legitimacy benefits accruing from connections to superior collaborators enhances self-esteem and positive perceptions about one's ability, however being connected to superior collaborators is not able to fulfill rewards and recognition expectation for the ego scientist, and as a result, the ego scientists reports a lower level of satisfaction with rewards.

Next, the indirect effect of resources received from collaborators on satisfaction with rewards at t2 is positive and significant (std. est. = 0.166; p value= 0.02), lending support for H4. The relationship between resources received from collaborative ties at t1 and satisfaction with rewards at t2 is mediated by two variables--salary at t2 and dollar amount of largest grant at t2. The positive effect suggests that receiving greater amount of resources from collaborators leads to changes in the intervening variables, which in turn lead to change in satisfaction with rewards, and this change is positive and significant. Scientists who receive greater amount of resources from their collaborators are able to convert those resources to rewards, and in turn report a higher level of satisfaction with rewards. The magnitude of the indirect effect between resources received at t1 and satisfaction with rewards at t2 can be estimated by multiplying the paths from resources received to salary, and resources received to dollar amount of largest grant, as well as paths from salary to satisfaction, and from dollar amount of largest grant to satisfaction. The computation is shown in the table below.

TABLE XVI. COMPUTING STANDARDIZED ESTIMATES OF THE INDIRECT EFFECTS OF RESOURCES RECEIVED ON SATISFACTION WITH REWARDS WITHOUT IMPUTATION

Indirect effect of resources received on satisfaction with rewards						
Resources--->salary--->satisfaction with rewards	=	0.137	*	0.181	=	0.024797
Resources--->grant large--->satisfaction with rewards	=	-0.074	*	-0.056	=	0.004144
		Adding all the indirect path coefficients				0.028941

Other indirect effects are also found such as the indirect effect of collaborative network constraint on salary as mediated by superior collaborators is positive and the size of this positive effect increases when the number of the number of superior collaborators decreases. Also, the indirect effect of collaborative network constraint on grant large mediated by superior collaborators is positive and the size of this positive effect increases when the number of the number of superior collaborators decreases.

5.6.5. Summary of main findings

The four main findings from the above model predicting satisfaction with rewards without imputation are as follows:

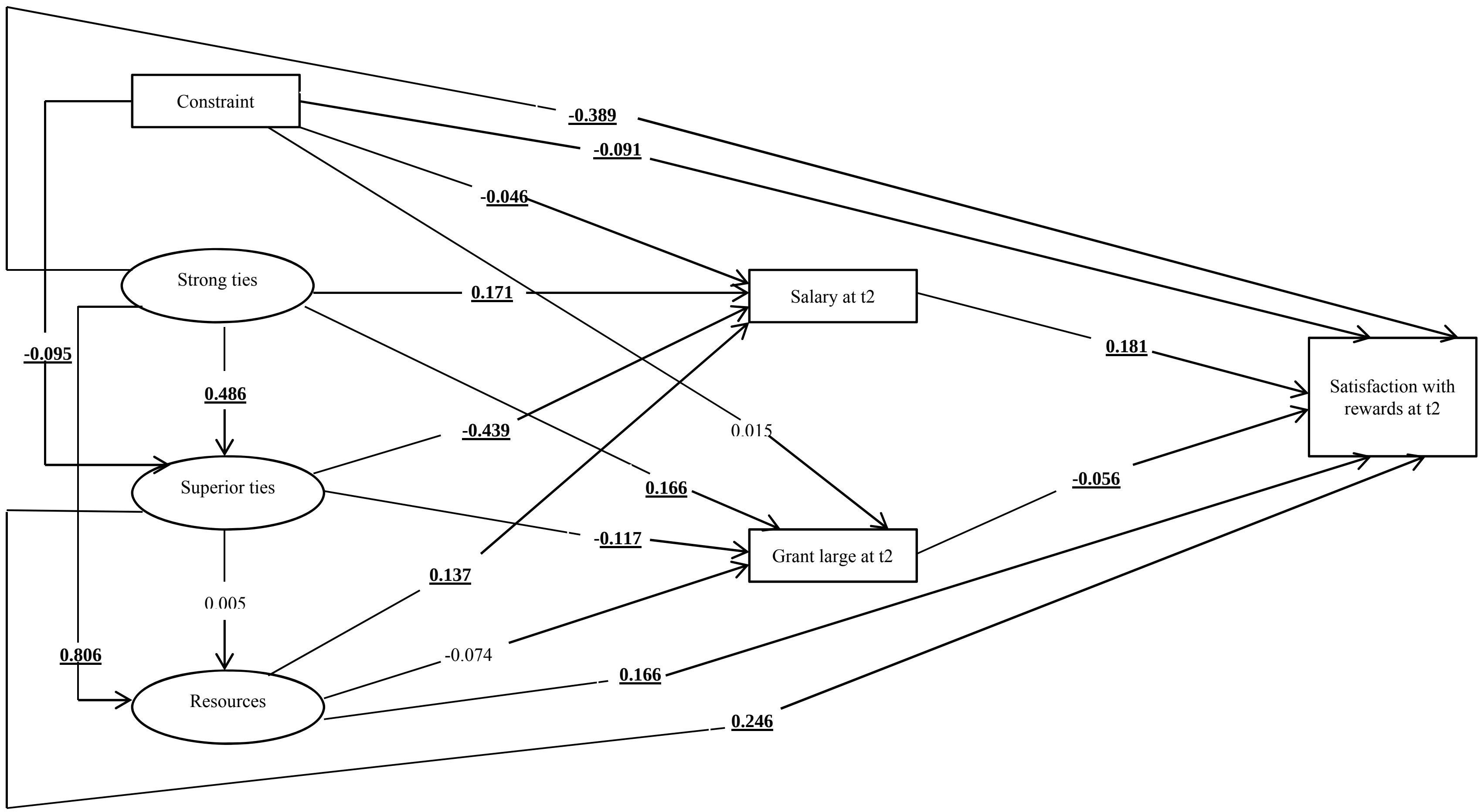
1) The total, direct, and indirect effect of collaborative network constraint on satisfaction with rewards is negative and significant (see fig 6 and table 10). This finding means that scientists located in constrained collaborative networks report a lower level of satisfaction with rewards because collaborative exchange with a relatively powerful collaborator in a constrained network results in lower receipt of rewards and recognition. The structurally powerful collaborator may be *controlling* and may withhold rewards and recognition from the ego scientist. The negative direct effect indicates that collaborative exchange with a relatively powerful collaborator creates negative perception of one's ability to attain rewards and recognition.

2) The indirect effects of strong collaborative ties on satisfaction with rewards is positive and significant, while the total and direct effect is negative and significant (see fig 6 and table 10). This finding suggests that strong collaborative ties result in greater access to resources, and greater rewards and recognition, as they are *reciprocal* in nature, leading to higher levels of satisfaction with rewards.

3) The indirect effect of connections to superior collaborators on satisfaction with rewards is negative and significant, while total and direct effect of collaborative network constraint on satisfaction with rewards is positive and significant (see fig 6 and table 10). The positive direct effect and negative indirect effect suggests that, the *validation* and *legitimacy* benefits accruing from connections to superior collaborators enhances self-esteem and positive perceptions about one's ability to attain rewards and recognition, however connections to a large number of superior collaborators in terms of seniority and grant getting ability does not generate enough rewards and recognition so as to fulfill ego scientist's reward expectations. As a result, the scientist reports a lower level of satisfaction with rewards.

4) The total, direct, and indirect effect of resources received from collaborators on satisfaction with rewards is positive and significant (see fig 6 and table 10). The positive indirect effect suggests that resources received from collaborators heighten *legitimacy*, and helps earn greater rewards and recognition, and consequently a higher level of satisfaction with rewards. The positive direct effect suggests that receiving greater amount of resources enhances self-esteem, and leads to positive evaluation of one's ability to achieve rewards and recognition.

Fig 16. Direct paths (standardized estimates): model predicting satisfaction with rewards at t2 (with weights and without imputation)



- **Estimates that are significant are in bold**
- **Controls are not shown for the sake of clarity**

TABLE XVII. TOTAL, DIRECT, AND INDIRECT EFFECTS (SATISFACTION WITH REWARDS MODEL WITH WEIGHTS AND WITHOUT IMPUTATION)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**
P1	Constraint--->superior ties	-0.095	0.019	0.01	-0.095	0.019	0.01	...	...	...
	Constraint--->resources	0.001	0.003	0.9	...	...	...	0.001	0.003	0.9
	Constraint--->salary at t2	-0.004	0.017	0.973	-0.046	0.019	0.025	0.042	0.009	0.01
	Constraint--->grant large at t2	0.026	0.018	0.126	0.015	0.018	0.39	0.011	0.003	0.01
H1	Constraint--->satisfaction with rewards at t2	-0.116	0.022	0.01	-0.091	0.022	0.01	-0.026	0.008	0.01
P3	Strong ties-->superior ties	0.486	0.024	0.01	0.486	0.024	0.01	...	...	...
P2	Strong ties--->resources	0.808	0.02	0.01	0.806	0.024	0.01	0.002	0.013	0.899
	Strong ties--->salary at t2	0.068	0.03	0.035	0.171	0.085	0.059	-0.103	0.067	0.145
	Strong ties--->grant large at t2	0.049	0.02	0.021	0.166	0.051	0.01	-0.117	0.047	0.024
H2a, H2b	Strong ties--->satisfaction with rewards at t2	-0.126	0.03	0.01	-0.389	0.086	0.01	0.264	0.068	0.01
P4	Superior ties--->resources	0.005	0.027	0.899	0.005	0.027	0.899	...	...	...
	Superior ties--->salary at t2	-0.439	0.02	0.01	-0.439	0.02	0.01	0.001	0.004	0.927
	Superior ties--->grant large at t2	-0.117	0.022	0.01	-0.117	0.022	0.01	0.000	0.003	0.882
H3a,H3b	Superior ties--->satisfaction with rewards at t2	0.174	0.058	0.01	0.246	0.059	0.01	-0.072	0.013	0.01
	Resources--->salary at t2	0.137	0.08	0.091	0.137	0.08	0.091	...	...	...
	Resources--->grant large at t2	-0.074	0.058	0.171	-0.074	0.058	0.171	...	...	...
H4	Resources--->satisfaction with rewards at t2	0.195	0.077	0.015	0.166	0.073	0.022	0.029	0.013	0.032
	Salary at t2--->satisfaction with rewards at t2	0.181	0.025	0.01	0.181	0.025	0.01	...	...	...
	Grant large at t2--->satisfaction with rewards at t2	-0.056	0.018	0.01	-0.056	0.018	0.01	...	...	...
	Receipt of organizational resources--->satisfaction with rewards at t2	0.095	0.019	0.01	0.095	0.019	0.01	...	...	...
	Number of publications at t1--->satisfaction with rewards at t2	0.059	0.026	0.023	0.059	0.026	0.023	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with rewards at t2	0.004	0.021	0.785	0.004	0.021	0.785	...	...	...
	Dept faculty size--->satisfaction with rewards at t2	-0.071	0.024	0.033	-0.071	0.024	0.033	...	...	...
	Female--->satisfaction with rewards at t2	-0.081	0.022	0.01	-0.081	0.022	0.01	...	...	...
	South or southeast asian--->satisfaction with rewards at t2	-0.017	0.022	0.459	-0.017	0.022	0.459	...	...	...
	Black/African American--->satisfaction with rewards at t2	0.059	0.017	0.01	0.059	0.017	0.01	...	...	...
	Hispanic--->satisfaction with rewards at t2	0.029	0.018	0.141	0.029	0.018	0.141	...	...	...
	Assistant Professor--->satisfaction with rewards at t2	-0.223	0.046	0.01	-0.223	0.046	0.01	...	...	...
	Associate Professor--->satisfaction with rewards at t2	-0.155	0.025	0.01	-0.155	0.025	0.01	...	...	...
	Physics--->satisfaction with rewards at t2	-0.088	0.026	0.01	-0.088	0.026	0.01	...	...	...
	Chemistry--->satisfaction with rewards at t2	-0.089	0.033	0.012	-0.089	0.033	0.012	...	...	...
	EAS-->satisfaction with rewards at t2	-0.046	0.027	0.081	-0.046	0.027	0.081	...	...	...
	CS--->satisfaction with rewards at t2	0.046	0.024	0.076	0.046	0.024	0.076	...	...	...
	EE--->satisfaction with rewards at t2	-0.071	0.026	0.01	-0.071	0.026	0.01	...	...	...

5.7. Model predicting satisfaction with rewards at t2 with regression imputation

The previous structural equation model was run without imputing for missing data. In the following section, the same model is run with imputed data i.e. missing values are replaced using regression imputation[3]. The findings are presented and discussed in the same format as the previous model i.e. confirmatory factor analysis findings will be presented first followed by model fit indices. Next, direct and indirect effects will be presented and discussed.

5.7.1. Confirmatory factor analysis: SEM model predicting satisfaction with rewards at t2 with regression imputation

For this model run with imputed data, among the indicator variables that define strong collaborative ties, duration of collaborative interaction (collabduration_sum) has the highest standardized factor loading of 0.837 and corresponding squared multiple correlations (R square) of 70%. This means that interaction duration explains a respectable portion of the variance in strong ties. The other two indicator variables that define strong collaborative ties are frequency of collaborative interaction and close friendship with collaborators, both of which have the standardized factor loading of 0.661, and 0.486 respectively. Frequency of collaborative interaction and close friendship with collaborators explain around 44% and 24% of the variance in strong ties.

Two indicator variables define the latent variable superior ties are number of senior collaborators (collabsenior_sum) and number of better grant getters (collabgrant_sum). The standardized factor loadings of number of senior collaborators, and better grant getters are 0.782, and 0.645 respectively with corresponding squared multiple correlations (R square) of 61% and 42% respectively.

Two indicators variables namely number of collaborators who provide introductions (collabintro_sum) and number of collaborators who provide nomination for awards (collabnom_sum) define the latent variable, resources received from collaborators. The

[3] Missing data can create problems for analyzing data; imputation is seen as a way to avoid pitfalls involved with listwise deletion. Models with missing data and with imputed data were run to see whether there are differences in findings. The model with missing data or without imputed data had a N of 535, a difference of 230 data points compared to model with imputation with N of 765.

standardized factor loadings of number of collaborators who provide introductions and number of collaborators who provide nominations for awards are 0.726, and 0.603 respectively with corresponding squared multiple correlations (R square) of 53% and 36% respectively.

Among the three indicator variables that define the dependent latent variable—satisfaction with rewards at time 2, workSatNew_r7 (faculty reward system at the institution) has the highest standardized factor loading of 0.924 and corresponding squared multiple correlations (R square) of 85%. This means that workSatNew_r7 explains a respectable portion of the variance in satisfaction with rewards at time t2. The other two indicator variables that define satisfaction with rewards are WorkSatNew_r6 (department's allocation of rewards for productivity) and WorkSatNew_r8 (salary), both of which have the standardized factor loading of 0.835, and 0.617 respectively. WorkSatNew_r6 and WorkSatNew_r8 explain around 70% and 42% of the variance in satisfaction with rewards at time t2 respectively.

TABLE XVIII. CONFIRMATORY FACTOR ANALYSIS—SATISFACTION WITH REWARDS WITH IMPUTATION

			Estimate	Std. Est.	S.E.	C.R.	P	R square
collabnom_sum	<-	Resources	1	0.603				0.363
collabintro_sum	<-	Resources	1.866	0.726	0.06	31.092	***	0.527
WorkSatNew_r6	<-	Satisfaction with rewards at t2	1	0.835				0.697
WorkSatNew_r7	<-	Satisfaction with rewards at t2	1.125	0.924	0.019	59.579	***	0.853
WorkSatNew_r8	<-	Satisfaction with rewards at t2	0.721	0.617	0.016	45.553	***	0.422
collabfriend_sum	<-	Strong ties	1	0.486				0.236
collabduration_sum	<-	Strong ties	2.483	0.837	0.086	28.787	***	0.70
collabgrant_sum	<-	Superior ties	1	0.645				0.417
collabsenior_sum	<-	Superior ties	1.379	0.782	0.035	39.022	***	0.612
collabfreq_sum	<-	Strong ties	1.347	0.661	0.045	30.254	***	0.437

5.7.2. Assessing model fit: SEM model predicting satisfaction with rewards at time t2 (with regression imputation)

Findings from this model suggest that RMSEA is 0.046, which indicates a good fit. Another fit index, comparative fit index (CFI) values equal or greater than 0.9 indicate a good fit. Findings from this model suggest that CFI is 0.917, which indicates a good fit. However, the chi square $\chi 2$ statistic is significant which indicates that the model is rejected.

5.7.3. Direct and indirect effects: SEM model predicting satisfaction with rewards at time t2 (with regression imputation)

For this model run with imputed data, path analysis showed several significant direct effects. The direct effect of strong collaborative ties on resources received from collaborators is positive and significant (std. est. =0.763; p value=0.01). This suggests that strong collaborative ties increase the amount of resources received by academic scientists *(P2)*. Similar to the previous model, path analysis findings showed reverse support for *P3*. Specifically, the direct effect of strong collaborative ties on superior collaborators is positive and significant (std. est. =0.403; p value=0.01). The positive sign suggests that academic scientists are more likely to be strongly tied to superior collaborators. Further, as expected, the direct effect of collaborative network constraint on number of superior collaborators is negative and significant *(P1)*. Specifically, scientists with higher constraint in their collaborative network have fewer superior collaborators in their network.

Next, among the direct effects between network factors and satisfaction with rewards at t2, path analysis findings showed a negative and significant direct effect between collaborative network constraint at t1 and satisfaction with rewards at t2 (std. est. =-0.056; p value=0.01). The negative direct effect of collaborative network constraint on satisfaction with rewards suggests that academic scientists located in structurally constrained network perceive being controlled by a relatively powerful collaborator, and form negative perceptions about their capability of fulfilling reward expectations.

Path analysis findings also showed a negative and significant direct effect between strong collaborative ties at t1 and satisfaction with rewards at t2 (std. est. = -0.35; p value=0.01). The negative sign suggests that having a large number of strong collaborative ties at t1 lowers satisfaction with rewards among academic scientists at t2. Perhaps the presence of a large number of strong collaborative ties creates perceptions of over dependence, incompetence, or lack of sense of control over ones work. Such perceptions are likely to lead to lower levels of satisfaction with rewards.

Further, the direct effect of connections to superior collaborators at t1 on satisfaction with rewards at t2 is positive and significant (std. est. = 0.14; p value=0.01). This finding suggests that academic scientists connected to a large number of superior collaborators perceive being socially valued, and legitimate, and hence form positive evaluations of their capability of fulfilling their reward expectations. Path analysis findings also showed a positive and significant direct effect of resources received from collaborators at t1 on satisfaction with rewards at t2 (std. est. = 0.198; p value=0.02). This positive direct effect suggests that receiving greater amount of resources from collaborators enhances self-esteem of academic scientists, and leads to positive evaluation of one's ability to achieve rewards and professional recognition. The academic scientist is aware that he or she is receiving resources from their collaborators, and as a result perceives being valued, and reports a higher level of satisfaction.

Similar to the previous model, path analysis findings showed several significant direct effects between networks and rewards. For example, the direct effect of collaborative network constraint at t1 on salary at t2 is negative and significant (std. est. = -0.034; p value=0.02). This negative effect suggests that academic scientists located in structurally constrained collaborative networks earn lower salary at t2. Another negative and significant direct effect is found between connections to superior collaborative ties at t1 and reward outcomes at t2. This suggests that scientists who are connected to a large number of superior collaborators in terms of seniority and grant getting ability earn lower salary at t2 as well as receive smaller grants in terms of dollar amounts. Perhaps, the negative direct effect of superior collaborators on reward outcomes may be explained from a social status perspective. Specifically, ego scientists connected to a large number of superior collaborators may be of lower status, and hence may be less likely to access and control resources essential to achieve rewards and professional recognition.

Several positive and significant direct effects were also found between networks and rewards. For example, the direct effect of being connected to a large number of strong collaborative ties on both reward outcomes (salary and dollar amount of largest grant) is positive and significant. Specifically, academic scientists connected to a large number of strong collaborative ties at t1 achieve higher levels of rewards at t2. Another positive and significant direct effect is found between resources received from collaborators at t1 and salary at t2. This finding means that academic scientists who receive greater amount of resources from their collaborators at t1 receive higher salary at t2. Interestingly, in this model, unlike the previous model which was run without imputing for missing data, the direct effect of collaborative network constraint on dollar amount of largest grant is positive and significant. Perhaps, constrained collaborative networks yield efficiency benefits required to write grant proposals and administer them.

Turning to the path analysis findings on the direct effects between rewards and satisfaction indicate that salary has a positive and significant direct effect on satisfaction with rewards at t2. This finding suggests that scientists who earn higher salary also report a higher a higher level of satisfaction with rewards. However, as in the previous model, the other reward outcome—dollar amount of largest grant has a negative and significant effect on satisfaction with rewards.

Similar to the previous model, among the relationships between non network and demographic control variables and satisfaction with rewards, the findings suggest that scientists who are located in department with large number of faculty report lower satisfaction with rewards. Perhaps, in large departments, there is greater competition to secure rewards, and scientists get lower level of rewards than they expect, resulting in a lower level of satisfaction with rewards. Scientists who receive greater amount of resources from their department report a higher level of satisfaction with rewards. Further, findings suggest that assistant professors and associate professors are less satisfied with rewards compared to full professors. Women scientists are less satisfied with rewards compared to men. Physicists, chemists, earth and environmental scientist, and electrical engineers are less satisfied with rewards compared to biologists. African American scientists are more satisfied with rewards compared to whites.

For this model, path analysis showed several indirect effects. First, the indirect effect of collaborative network constraint at t1 on satisfaction with rewards at t2 is negative and significant (std. est. = -0.017; p value=0.01), supporting (H1). This means that for every one unit increase in constraint, a decrease of -0.017 unit of satisfaction with rewards is predicted through the effects of constraint on the intervening variables (salary at t2, dollar amount of largest grant at t2 and superior ties at t1). The negative indirect effect indicates that collaborative network constraint leads to changes in the intervening variables, which in turn lead to change in satisfaction with rewards, and this change is negative and significant. Note that the total and direct effect of collaborative network constraint on satisfaction with rewards is also negative and significant which suggests that there is little evidence for complete mediation of the intervening variables. The indirect effect of constraint can also be calculated by adding the product of indirect paths from constraint to satisfaction with rewards (see table below).

TABLE XIX. COMPUTING STANDARDIZED ESTIMATES OF THE INDIRECT EFFECTS OF COLLABORATIVE NETWORK CONSTRAINT ON SATISFACTION WITH REWARDS WITH IMPUTATION

Indirect effect of constraint on satisfaction with rewards										
Constraint-->Superior ties-->satisfaction with rewards	=	-0.116	*	0.14	*				=	-0.01624
Constraint-->Superior ties-->salary-->satisfaction with rewards	=	-0.116	*	-0.467	*	0.225	*		=	0.0121887
Constraint-->Superior ties-->grant large-->satisfaction with rewards	=	-0.116	*	-0.085	*	-0.051	*		=	-0.0005029
Constraint-->salary-->satisfaction with rewards	=	-0.034	*	0.225	*				=	-0.00765
Constraint-->grant large-->satisfaction with rewards	=	0.037	*	-0.051	*				=	-0.001887
Constraint-->Superior ties-->resources-->salary-->satisfaction with rewards	=	-0.116	*	0.093	*	0.174	*	0.225	=	-0.0004224
Constraint-->Superior ties-->resources-->grant large-->satisfaction with rewards	=	-0.116	*	0.093	*	-0.062	*	-0.051	=	-3.41E-05
Constraint-->Superior ties-->resources-->satisfaction with rewards	=	-0.116	*	0.093	*	0.198			=	-0.002136
Adding all the indirect path coefficients										-0.0166836

The indirect effect of strong collaborative ties on satisfaction with rewards is found to be positive and significant (std. est. = 0.241; p value= 0.01), supporting (H2a). This means that for every one unit increase in strong collaborative ties, an increase of 0.264 unit of satisfaction with rewards is predicted through the effects of strong collaborative ties on the intervening variables (salary at t2, dollar amount of largest grant at t2, superior ties at t1, and resources received at t1). The positive indirect effect tells us that strong ties leads to changes in the intervening variables, which in turn leads to change in satisfaction with rewards and this change is positive and significant. Although the indirect effect of strong collaborative ties on satisfaction with rewards is positive and significant, there is little evidence for complete mediation of the intervening variables because the direct effect of strong collaborative ties on satisfaction with rewards is negative and significant (Lacobucci, 2008). The total effect of strong collaborative ties on satisfaction with rewards is also negative and significant. The negative direct effect and positive indirect effect of strong collaborative ties on satisfaction with rewards may suggest that it is through the effects of rewards and recognition, and other intervening network variables that strong ties are able to fulfill ego scientist's reward expectations. The indirect effect of strong ties on satisfaction with rewards is computed in the table below.

TABLE XX. COMPUTING STANDARDIZED ESTIMATES OF THE INDIRECT EFFECTS OF STRONG COLLABORATIVE TIES ON SATISFACTION WITH REWARDS WITH IMPUTATION

Indirect effects of strong ties on satisfaction									
Strong ties-->superior ties-->satisfaction with rewards	0.403	*	0.14					=	0.05642
Strong ties-->superior ties-->salary-->satisfaction with rewards	0.403	*	-0.467	*	0.225			=	-0.0423452
Strong ties-->superior ties-->grant large-->satisfaction with rewards	0.403	*	-0.085	*	-0.051			=	0.001747
Strong ties-->superior ties-->resources-->satisfaction with rewards	0.403	*	0.093	*	0.198			=	0.0074208
Strong ties-->superior ties-->resources-->salary-->satisfaction with rewards	0.403	*	0.093	*	0.174	*	0.225	=	1.47E-03
Strong ties-->superior ties-->resources-->grant large-->satisfaction with rewards	0.403	*	0.093	*	-0.062	*	-0.051	=	1.19E-04
Strong ties-->resources-->satisfaction with rewards	0.763	*	0.198					=	0.151074
Strong ties-->resources-->salary-->satisfaction with rewards	0.763	*	0.174	*	0.225			=	0.0298715
Strong ties-->resources-->grant large-->satisfaction with rewards	0.763	*	-0.062	*	-0.051			=	0.0024126
Strong ties-->salary-->satisfaction with rewards	0.183	*	0.225					=	0.041175
Strong ties-->grant large-->satisfaction with rewards	0.151	*	-0.051					=	-0.007701
	Adding all the indirect path coefficients (last column)							=	2.42E-01

Further, as in the previous model, the indirect effect of connections to superior collaborators at t1 on satisfaction with rewards at t2 is negative and significant ((std. est. = -0.079; p value= 0.01), supporting (H3b). This means that for every one unit increase in the number of superior collaborators, a decrease of -0.079 unit of satisfaction with rewards is predicted through the effects of superior collaborators on the intervening variables (salary at t2, dollar amount of largest grant at t2 and resources received at t1). The negative indirect effect indicates that connections to superior collaborators leads to changes in the intervening variables, which in turn lead to change in satisfaction with rewards, and this change is negative and significant. Scientists connected to a large number of superior collaborators are not able to convert those connections to rewards, and in turn report a lower level of satisfaction with rewards. The total and direct effect of collaborative network constraint on satisfaction with rewards is positive and significant which suggests that there is little evidence for complete mediation of the intervening variables. The positive direct effect and negative indirect effect of connections to superior collaborators on satisfaction with rewards at t2 suggests that, the validation and legitimacy benefits accruing from connections to superior collaborators enhances self-esteem and positive perceptions about one's ability, however being connected to superior collaborators is not able to increase rewards and recognition for the ego scientist, and as a result, the ego scientist is not able to fulfill his or her reward expectations, and hence reports a lower level of satisfaction with rewards.

Next, the indirect effect of resources received from collaborators on satisfaction with rewards at t2 is positive and significant (std. est. = 0.042; p value= 0.02), lending support for H4. The relationship between resources received from collaborative ties at t1 and satisfaction with rewards at t2 is mediated by two variables—salary at t2 and dollar amount of largest grant at t2. The positive effect suggests that receiving greater amount of resources from collaborators leads to changes in the intervening variables, which in turn lead to change in satisfaction with rewards, and this change is positive and significant. Scientists who receive greater amount of resources from their collaborators are able to convert those resources to rewards, and in turn report a higher level of satisfaction with rewards.

Other indirect effects are also found such as the indirect effect of collaborative network constraint on salary as mediated by superior collaborators is positive and the size of this positive effect increases when the number of the number of superior collaborators decreases. Also, the indirect effect of collaborative network constraint on dollar amount of largest grant mediated by superior collaborators is positive and the size of this positive effect increases when the number of the number of superior collaborators decreases. Next, the indirect effect of strong ties on resources received is positive, and the size of this positive effect increases when superiors increase.

5.7.4. Summary of main findings of the above structural equation model predicting satisfaction with rewards run with regression imputation

The four main findings from the above model predicting satisfaction with rewards with regression imputation are similar to the previous model run without imputing for missing data. They are as follows:

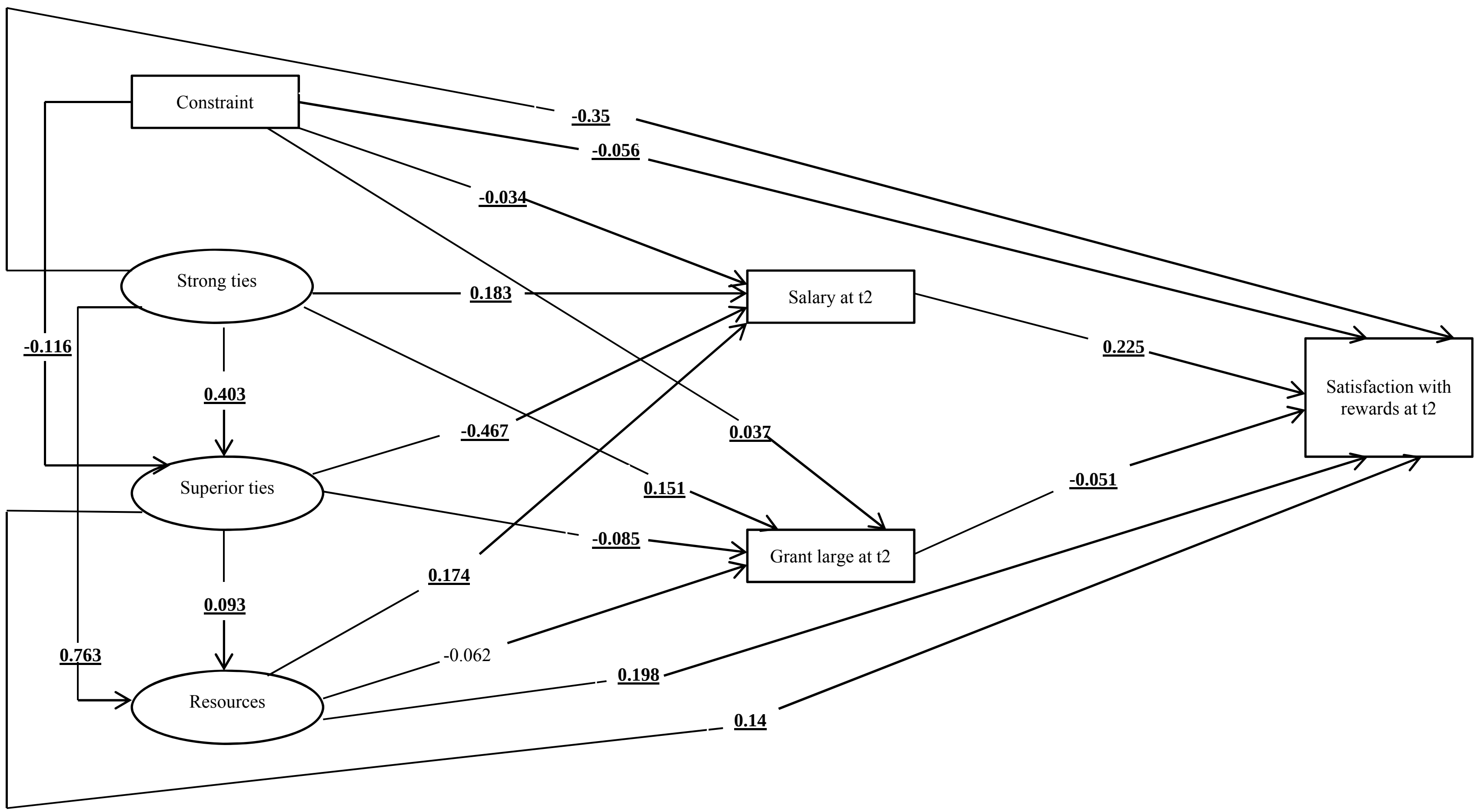
1) Similar to the previous model, the total, direct, and indirect effect of collaborative network constraint on satisfaction with rewards is negative and significant (see fig 7 and table 14). This finding means that scientists located in constrained collaborative networks report a lower level of satisfaction with rewards because collaborative exchange with a relatively powerful collaborator in a constrained network results in lower receipt of rewards and recognition. The structurally powerful collaborator may be *controlling* and may withhold rewards and recognition from the ego scientist. The negative direct effect indicates that collaborative exchange with a relatively powerful collaborator creates negative perception of one's ability to attain rewards and recognition.

2) The indirect effects of strong collaborative ties on satisfaction with rewards is positive and significant, while the total and direct effect is negative and significant (see fig 7 and table 14). This finding suggests that strong collaborative ties result in greater access to resources, and greater rewards and recognition, as they are *reciprocal* in nature, leading to higher levels of satisfaction with rewards.

3) The indirect effect of connections to superior collaborators on satisfaction with rewards is negative and significant, while total and direct effect of collaborative network constraint on satisfaction with rewards is positive and significant (see fig 7 and table 14). The positive direct effect and negative indirect effect suggests that, the *validation* and *legitimacy* benefits accruing from connections to superior collaborators enhances self-esteem and positive perceptions about one's ability to attain rewards and recognition, however connections to a large number of superior collaborators in terms of seniority and grant getting ability does not generate enough rewards and recognition so as to fulfill ego scientist's reward expectations. As a result, the scientist reports a lower level of satisfaction with rewards.

4) The total, direct, and indirect effect of resources received from collaborators on satisfaction with rewards is positive and significant (see fig 7 and table 14). The positive indirect effect suggests that resources received from collaborators heighten *legitimacy*, and helps earn greater rewards and recognition, and consequently a higher level of satisfaction with rewards. The positive direct effect suggests that receiving greater amount of resources enhances self-esteem, and leads to positive evaluation of one's ability to achieve rewards and recognition.

Fig 17. Direct paths (standardized estimates): model predicting satisfaction with rewards at t2 (with weights and with imputation)



- **Estimates that are significant are in bold**
- **Controls are not shown for the sake of clarity**

TABLE XXI. TOTAL, DIRECT, AND INDIRECT EFFECTS (SATISFACTION WITH REWARDS MODEL WITH WEIGHTS AND WITH IMPUTATION)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint--->superior ties	-0.116	0.015	0.01	-0.116	0.015	0.01	...	...	...
	Constraint--->resources	-0.011	0.003	0.01	...	...	...	-0.011	0.003	0.01
	Constraint--->salary at t2	0.019	0.013	0.136	-0.034	0.014	0.033	0.052	0.007	0.01
	Constraint--->grant large at t2	0.047	0.016	0.015	0.037	0.016	0.041	0.01	0.003	0.01
H1	Constraint--->satisfaction with rewards at t2	-0.073	0.017	0.01	-0.056	0.017	0.01	-0.017	0.006	0.01
P3	Strong ties-->superior ties	0.403	0.021	0.01	0.403	0.021	0.01	...	...	...
P2	Strong ties--->resources	0.8	0.018	0.01	0.763	0.019	0.01	0.037	0.008	0.01
	Strong ties--->salary at t2	0.134	0.03	0.01	0.183	0.099	0.095	-0.049	0.075	0.404
	Strong ties--->grant large at t2	0.067	0.016	0.01	0.151	0.041	0.01	-0.084	0.036	0.024
H2a, H2b	Strong ties--->satisfaction with rewards at t2	-0.109	0.027	0.01	-0.35	0.068	0.01	0.241	0.052	0.01
P4	Superior ties--->resources	0.093	0.021	0.01	0.093	0.021	0.01	...	...	...
	Superior ties--->salary at t2	-0.45	0.016	0.01	-0.467	0.018	0.01	0.016	0.01	0.059
	Superior ties--->grant large at t2	-0.091	0.019	0.01	-0.085	0.019	0.01	-0.006	0.005	0.118
H3a,H3b	Superior ties--->satisfaction with rewards at t2	0.062	0.042	0.202	0.14	0.044	0.01	-0.079	0.014	0.01
	Resources--->salary at t2	0.174	0.096	0.059	0.174	0.096	0.059	...	...	...
	Resources--->grant large at t2	-0.062	0.047	0.118	-0.062	0.047	0.118	...	...	...
H4	Resources--->satisfaction with rewards at t2	0.24	0.068	0.01	0.198	0.06	0.01	0.042	0.018	0.028
	Salary at t2--->satisfaction with rewards at t2	0.225	0.022	0.01	0.225	0.022	0.01	...	...	...
	Grant large at t2--->satisfaction with rewards at t2	-0.051	0.015	0.01	-0.051	0.015	0.01	...	...	...
	Receipt of organizational resources--->satisfaction with rewards at t2	0.075	0.016	0.01	0.075	0.016	0.01	...	...	...
	Number of publications at t1--->satisfaction with rewards at t2	0.019	0.02	0.311	0.019	0.02	0.311	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with rewards at t2	0.029	0.017	0.086	0.029	0.017	0.086	...	...	...
	Dept faculty size--->satisfaction with rewards at t2	-0.046	0.019	0.04	-0.046	0.019	0.04	...	...	...
	Female--->satisfaction with rewards at t2	-0.088	0.017	0.01	-0.088	0.017	0.01	...	...	...
	South or southeast asian--->satisfaction with rewards at t2	0.001	0.017	0.898	0.001	0.017	0.898	...	...	...
	Black/African American--->satisfaction with rewards at t2	0.056	0.014	0.01	0.056	0.014	0.01	...	...	...
	Hispanic--->satisfaction with rewards at t2	-0.008	0.015	0.652	-0.008	0.015	0.652	...	...	...
	Assistant Professor--->satisfaction with rewards at t2	-0.124	0.034	0.01	-0.124	0.034	0.01	...	...	...
	Associate Professor--->satisfaction with rewards at t2	-0.097	0.018	0.01	-0.097	0.018	0.01	...	...	...
	Physics--->satisfaction with rewards at t2	-0.106	0.02	0.01	-0.106	0.02	0.01	...	...	...
	Chemistry--->satisfaction with rewards at t2	-0.11	0.024	0.01	-0.11	0.024	0.01	...	...	...
	EAS-->satisfaction with rewards at t2	-0.023	0.019	0.232	-0.023	0.019	0.232	...	...	...
	CS--->satisfaction with rewards at t2	0.046	0.02	0.028	0.046	0.02	0.028	...	...	...
	EE--->satisfaction with rewards at t2	-0.073	0.02	0.01	-0.073	0.02	0.01	...	...	...

5.8. SEM model predicting satisfaction with reputation of department and institution without imputation

The previous sections presented and discussed findings for the structural equation models predicting satisfaction with rewards at t2 without and with imputation respectively. In this section, two structural equation models are run predicting satisfaction with reputation of department and institution at t2 without and with imputation respectively. Findings for both of these models are presented in the following format. First, confirmatory factor analysis findings are presented followed by model fit indices. Finally, path analysis findings (direct and indirect effects) are presented and discussed.

5.8.1. Confirmatory factor analysis: SEM model predicting satisfaction with reputation of department and institution without imputation

Among the indicator variables that define strong collaborative ties, duration of collaborative interaction (collabduration_sum) has the highest standardized factor loading of 0.89 and corresponding squared multiple correlations (R square) of 79%. This means that interaction duration explains a respectable portion of the variance in strong ties. The other two indicator variables that define strong ties are frequency of collaborative interaction and close friendship with collaborators, both of which have the standardized factor loading of 0.588, and 0.424 respectively. Frequency of collaborative interaction and close friendship with collaborators explain around 35% and 18% of the variance in strong collaborative ties.

Two indicator variables define the latent variable superior collaborative ties are number of senior collaborators (collabsenior_sum) and number of better grant getters (collabgrant_sum). The standardized factor loadings of number of senior collaborators, and better grant getters are 0.806, and 0.582 respectively with corresponding squared multiple correlations (R square) of 65% and 34% respectively.

Two indicators variables namely number of collaborators who provide introductions (collabintro_sum) and number of collaborators who provide nomination for awards (collabnom_sum) define the latent variable, resources received from collaborators. The standardized factor loadings of number of collaborators who provide introductions and number of collaborators who provide nominations for awards are 0.741, and 0.6 respectively with corresponding squared multiple correlations (R square) of 55% and 36% respectively.

Among the two indicator variables that define the dependent latent variable—satisfaction with reputation of department and institution at time t2, workSatNew_r4 (satisfaction with reputation of your department) has the highest standardized factor loading of 0.99 and corresponding squared multiple correlations (R square) of 99%. This means that workSatNew_r4 explains a respectable portion of the variance in satisfaction with reputation of department and institution at time t2. The other indicator variable that define satisfaction with reputation of department and institution is WorkSatNew_r5 (satisfaction with reputation of your institution) and it has the standardized factor loading of 0.698. WorkSatNew_r5 explains around 49% of the variance in satisfaction with reputation of department and institution at time t2.

TABLE XXII. CONFIRMATORY FACTOR ANALYSIS—SATISFACTION WITH REPUTATION OF DEPARTMENT AND INSTITUTION WITHOUT IMPUTATION

			Est.	Std. Est.	S.E.	C.R.	P	R square
collabnom_sum	<---	Resources	1	0.6				0.36
collabintro_sum	<---	Resources	2.035	0.741	0.081	25.156	***	0.549
WorkSatNew_r4	<---	Satisfaction with reputation of dept. and inst at t2	1.436	0.998	0.074	19.453	***	0.997
WorkSatNew_r5	<---	Satisfaction with reputation of dept. and inst at t2	1	0.698				0.488
collabfriend_sum	<---	Strong ties	1	0.424				0.18
collabduration_sum	<---	Strong ties	2.972	0.89	0.132	22.548	***	0.793
collabfreq_sum	<---	Strong ties	1.375	0.588	0.06	22.957	***	0.346
collabgrant_sum	<---	Superior ties	1	0.582				0.339
collabsenior_sum	<---	Superior ties	1.613	0.806	0.055	29.204	***	0.649

5.8.2. Assessing model fit: SEM model predicting satisfaction with reputation of department and institution without imputation

Findings from this model suggest that RMSEA is 0.05, which indicates a moderate fit. Another fit index, comparative fit index (CFI) for this model is 0.862, which also indicates a moderate fit. The chi square $\chi 2$ statistic is significant which indicates that the model is rejected.

5.8.3. Direct and indirect effects: SEM model predicting satisfaction with reputation of department and institution without imputation

Path analysis found several significant direct effects. Two of the four propositions were supported in this model predicting satisfaction with reputation of department and institution at t2. First, support is found for *P1*. Specifically, the direct effect of collaborative network constraint on superior collaborators is negative and significant (std. est. = -0.102; p value= 0.01). This finding suggests that scientists located in highly constrained collaborative network are less likely to be connected to superior collaborators in terms of seniority and grant getting ability. Next, the direct effect of strong collaborative ties on resources received from collaborators is positive and significant (std. est. =0.746; p value=0.01). This finding suggests that strong collaborative ties increase the amount of resources received by academic scientists, supporting *(P2)*. Path analysis finding showed reverse support for *P3*. Specifically, the direct effect of strong collaborative ties on superior collaborators is also positive and significant (std. est. =0.397; p value=0.01) rather than negative as was proposed in chapter 3. The positive sign means that academic scientists connected to a large number of strong collaborative ties are also connected to collaborators who are superior in terms of seniority and grant getting ability. This model did not find support for *P4*.

Next, among the direct effects between network factors and satisfaction with reputation of department and institution at t2, path analysis findings showed a negative and significant direct effect between collaborative network constraint at t1 and satisfaction with reputation of department and institution at t2 (std. est. =-0.131; p value=0.01). The negative direct effect of collaborative network constraint on satisfaction with reputation of department and institution suggests that academic scientists located in structurally constrained network perceive being controlled by a relatively powerful collaborator, and may form negative perceptions about themselves and their department and institution. Specifically, in collaborative exchange with a relatively powerful collaborator, the less powerful ego scientist may not be able to access and control resources, may perceive himself or herself to be less legitimate, and may form negative perceptions about their department and institution. Such negative perceptions may lead to lower levels of satisfaction with reputation of department and institution. Previous research has also found actors located in structurally disadvantageous locations report lower levels of satisfaction (Dean and Brass, 1985; Ibarra and Andrews, 1993; Rice and Mitchell, 1973; Settoon et al, 1996).

Further, the direct effect of connections to superior collaborators at t1 on satisfaction with reputation of department and institution at t2 is negative and significant (std. est. = -0.195; p value=0.01). This negative direct effect may be explained from a social status perspective. Specifically, social status perspective argues that connection to higher status collaborators lowers the status of the ego scientist. Lower status may lead to negative perceptions about oneself and about one's department and institution, leading to lower levels of satisfaction with the reputation of department and institution. The indirect effect of connections to superior collaborators at t1 on satisfaction with reputation of department and institution at t2 is not significant.

Path analysis findings also showed several significant direct effects between networks and rewards. For example, the direct effect found between connections to superior collaborative ties at t1 and reward outcomes (salary and dollar amount of largest grant) at t2 is found to be negative and significant. This suggests that scientists who are connected to a large number of superior collaborators in terms of seniority and grant getting ability earn lower salary at t2 as well as receive smaller grants in terms of dollar amounts. Specifically, connections to large number of superior collaborators in terms of seniority and grant getting ability at t1 tend to reduce both reward outcomes at t2. Perhaps, this negative direct effect may be explained from a social status perspective. Specifically, connection to higher status collaborators lowers the status of the ego scientist. Ego scientists of lower status may be less likely to access and control resources essential to achieve rewards and professional recognition.

Several positive and significant direct effects were also found between networks and rewards. For example, the direct effect of being connected to a large number of strong collaborative ties on both reward outcomes (salary and dollar amount of largest grant) is positive and significant. Specifically, academic scientists connected to a large number of strong collaborative ties at t1 achieve higher levels of rewards at t2. When scientists engage in collaborative exchange with strong ties, they offer their knowledge to their strong collaborative ties and in turn receive greater levels of rewards and professional recognition because strong collaborative ties are reciprocal in nature.

Path analysis findings on the relationship between reward outcomes and satisfaction with reputation of department and institution suggest that the direct effect of salary on and satisfaction with reputation of department and institution is positive and significant. This means that scientists who earn higher salaries are satisfied with the reputation of their department and institution. Among the relationships between non network and demographic control variables and satisfaction with reputation of department and institution, the findings suggest that scientists who are located in department with large number of faculty report higher satisfaction with reputation of their department and institution. Further, scientists who publish more report a higher level of satisfaction with reputation of their department and institution. Scientists who teach or co teach greater number of resources report a lower level of satisfaction with reputation of their department and institution. Associate professors are less satisfied with reputation of their department and institution compared to full professors. Women scientists are less satisfied with reputation of their department and institution compared to men. Earth and environmental scientists are more satisfied with reputation of their department and institution compared to biologists. African American scientists are more satisfied with reputation of their department and institution compared to whites.

Unlike the previous models predicting satisfaction with rewards at t2, this model predicting satisfaction with reputation of department and institution at t2 finds comparatively few indirect effects. The only indirect effect between collaborative network and satisfaction with reputation of department and institution is found between collaborative network constraint and satisfaction with reputation of department and institution. Specifically, the indirect effect of collaborative network at t1 on satisfaction with reputation of department and institution at t2 is positive and significant (std. est. = 0.021; p value=0.01. However, the positive indirect effect is not through rewards and recognition. In other words, although the indirect effect of collaborative network constraint on satisfaction with reputation of department and institution is positive and significant, the indirect effect does not occur through the mediating influence of salary and dollar amount of largest grant but through other intervening variables. Interestingly, the total and direct effect of collaborative network constraint on satisfaction with reputation of department and institution is negative and significant which suggests that there is little evidence for complete mediation of the intervening variables.

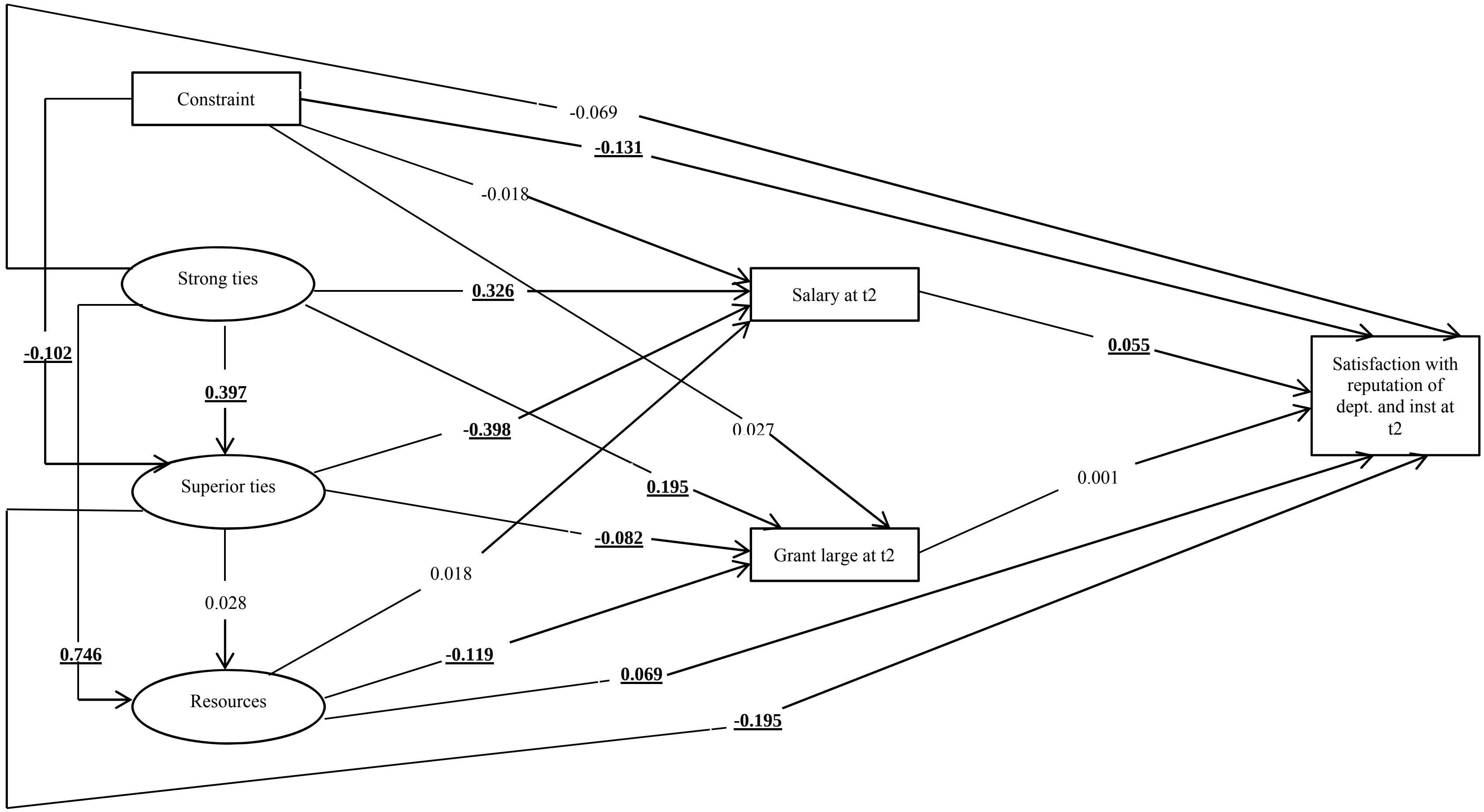
Other significant indirect effect exists between collaborative network constraint and salary at t2. Said in another way, the indirect effect of collaborative network constraint on salary is positive and significant. This means that as constraint in scientist's collaborative network increases, rewards also increase through the effect of constraint on the intervening variable. The intervening variable in this case is superior collaborative ties. The magnitude of this indirect effect of constraint on rewards can be estimated by multiplying the paths from constraint to superior collaborators, and from superior collaborators to rewards. Specifically, the standardized path coefficient from constraint to superior collaborators is -0.102 and the standardized path coefficient from superior collaborators to salary is -0.398, and the product of these two paths yields the indirect effect from constraint to salary earned as 0.041. Next, the indirect effect of collaborative network constraint on dollar amount of largest grant is also positive and significant. However, there is little evidence of complete mediation of intervening variables because the direct effect of collaborative network constraint on dollar amount of largest grant is positive and significant.

Further, the indirect effect of strong collaborative ties on both reward outcomes is negative and significant. The negative indirect effect indicates that strong collaborative ties lead to changes in the intervening variables, which in turn lead to change in salary and this change is negative and significant. The intervening variables mediating the relationship between strong collaborative ties and reward outcomes are superior collaborators and resources received from collaborators. Note that the total and direct effect of strong collaborative ties on both reward outcomes is positive and significant which suggests that there is little evidence for complete mediation of the intervening variables.

5.8.4. Summary of findings of the above structural equation model predicting satisfaction with reputation of department and institution run without imputation

The main finding is that the indirect effect of collaborative network constraint on satisfaction with reputation of department and institution is positive and significant, while the total and direct effect is negative (see fig 8 and table 17). However, the positive indirect effect is not through rewards and recognition. In other words, although the indirect effect of collaborative network constraint on satisfaction with reputation of department and institution is positive and significant, the indirect effect does not occur through the mediating influence of salary and dollar amount of largest grant.

Fig 18. Direct paths (standardized estimates): model predicting satisfaction with reputation of department and institution at t2 (with weights and without imputation)



- **Estimates that are significant are in bold**
- **Controls are not shown for the sake of clarity**

TABLE XXIII. TOTAL, DIRECT, AND INDIRECT EFFECTS (SATISFACTION WITH REPUTATION OF DEPARTMENT AND INSTITUTION WITHOUT IMPUTATION)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint--->superior ties	-0.102	0.018	0.01	-0.102	0.018	0.01	...	...	...
	Constraint--->resources	-0.003	0.003	0.276	...	...	...	-0.003	0.003	0.276
	Constraint--->salary at t2	0.023	0.017	0.159	-0.018	0.017	0.314	0.041	0.008	0.01
	Constraint--->grant large at t2	0.036	0.018	0.058	0.027	0.019	0.158	0.009	0.003	0.01
H1	Constraint--->satisfaction with reputation of dept. and inst at t2	-0.11	0.032	0.01	-0.131	0.031	0.01	0.021	0.007	0.01
P3	Strong ties-->superior ties	0.397	0.023	0.01	0.397	0.023	0.01	...	...	...
P2	Strong ties--->resources	0.757	0.018	0.01	0.746	0.021	0.01	0.011	0.009	0.276
	Strong ties--->salary at t2	0.154	0.019	0.01	0.326	0.044	0.01	-0.172	0.039	0.01
	Strong ties--->grant large at t2	0.072	0.021	0.01	0.195	0.056	0.01	-0.123	0.047	0.01
H2a, H2b	Strong ties--->satisfaction with reputation of dept. and inst at t2	-0.085	0.034	0.014	-0.069	0.057	0.222	-0.016	0.04	0.731
P4	Superior ties--->resources	0.028	0.024	0.276	0.028	0.024	0.276	...	...	...
	Superior ties--->salary at t2	-0.399	0.024	0.01	-0.398	0.024	0.01	-0.001	0.002	0.795
	Superior ties--->grant large at t2	-0.086	0.022	0.01	-0.082	0.022	0.01	-0.003	0.003	0.295
H3a, H3b	Superior ties--->satisfaction with reputation of dept. and inst at t2	-0.215	0.05	0.01	-0.195	0.053	0.01	-0.02	0.012	0.13
	Resources--->salary at t2	-0.018	0.046	0.747	-0.018	0.046	0.747	...	...	...
	Resources--->grant large at t2	-0.119	0.059	0.024	-0.119	0.059	0.024	...	...	...
H4	Resources--->satisfaction with reputation of dept. and inst at t2	0.068	0.041	0.102	0.069	0.041	0.087	-0.001	0.004	0.783
	Salary at t2--->satisfaction with reputation of dept. and inst at t2	0.055	0.03	0.067	0.055	0.03	0.067	...	...	...
	Grant large at t2--->satisfaction with reputation of dept. and inst at t2	0.001	0.017	0.826	0.001	0.017	0.826	...	...	...
	Receipt of organizational resources--->satisfaction with reputation of dept. and inst at t2	0.041	0.021	0.046	0.041	0.021	0.046	...	...	...
	Number of publications at t1--->satisfaction with reputation of dept. and inst at t2	0.129	0.022	0.01	0.129	0.022	0.01	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with reputation of dept. and inst at t2	-0.067	0.018	0.01	-0.067	0.018	0.01	...	...	...
	Dept faculty size--->satisfaction with reputation of dept. and inst at t2	0.154	0.019	0.01	0.154	0.019	0.01	...	...	...
	Female--->satisfaction with reputation of dept. and inst at t2	-0.034	0.018	0.08	-0.034	0.018	0.08	...	...	...
	South or southeast asian--->satisfaction with reputation of dept. and inst at t2	0.025	0.017	0.197	0.025	0.017	0.197	...	...	...
	Black/African American--->satisfaction with reputation of dept. and inst at t2	0.048	0.016	0.01	0.048	0.016	0.01	...	...	...
	Hispanic--->satisfaction with reputation of dept. and inst at t2	0.018	0.024	0.41	0.018	0.024	0.41	...	...	...
	Assistant Professor--->satisfaction with reputation of dept. and inst at t2	-0.029	0.047	0.603	-0.029	0.047	0.603	...	...	...
	Associate Professor--->satisfaction with reputation of dept. and inst at t2	-0.046	0.026	0.082	-0.046	0.026	0.082	...	...	...
	Physics--->satisfaction with reputation of dept. and inst at t2	-0.031	0.022	0.218	-0.031	0.022	0.218	...	...	...
	Chemistry--->satisfaction with reputation of dept. and inst at t2	-0.028	0.026	0.301	-0.028	0.026	0.301	...	...	...
	EAS-->satisfaction with reputation of dept. and inst at t2	0.154	0.022	0.01	0.154	0.022	0.01	...	...	...
	CS--->satisfaction with reputation of dept. and inst at t2	0.028	0.023	0.268	0.028	0.023	0.268	...	...	...
	EE--->satisfaction with reputation of dept. and inst at t2	-0.015	0.022	0.486	-0.015	0.022	0.486	...	...	...

5.9. SEM model 1 predicting satisfaction with reputation of department and institution with imputation

The previous model presented and discussed findings for the structural equation model predicting satisfaction with reputation of department and institution at t2 without imputing for missing data. In this section, the same model is run after imputing for missing data. Findings from this model are presented in the following format. First, confirmatory factor analysis findings are presented followed by model fit indices. Finally, path analysis findings (direct and indirect effects) are presented and discussed.

5.9.1. Confirmatory factor analysis: SEM model predicting satisfaction with reputation of department and institution with imputation

Among the indicator variables that define strong collaborative ties, duration of collaborative interaction (collabduration_sum) has the highest standardized factor loading of 0.905 and corresponding squared multiple correlations (R square) of 82%. This means that interaction duration explains a respectable portion of the variance in strong ties. The other two indicator variables that define strong ties are frequency of collaborative interaction and close friendship with collaborators, both of which have the standardized factor loading of 0.638, and 0.468 respectively. Frequency of collaborative interaction and close friendship with collaborators explain around 40% and 22% of the variance in strong collaborative ties.

Two indicator variables define the latent variable superior collaborative ties are number of senior collaborators (collabsenior_sum) and number of better grant getters (collabgrant_sum). The standardized factor loadings of number of senior collaborators, and better grant getters are 0.66, and 0.737 respectively with corresponding squared multiple correlations (R square) of 44% and 54% respectively.

Two indicators variables namely number of collaborators who provide introductions (collabintro_sum) and number of collaborators who provide nomination for awards (collabnom_sum) define the latent variable, resources received from collaborators. The standardized factor loadings of number of collaborators who provide introductions and number of collaborators who provide nominations for awards are 0.712, and 0.596 respectively with corresponding squared multiple correlations (R square) of 51% and 36% respectively.

Among the two indicator variables that define the dependent latent variable—satisfaction with reputation of department and institution at time t2, workSatNew_r4 (satisfaction with reputation of your department) has the highest standardized factor loading of 0.99 and corresponding squared multiple correlations (R square) of 98%. This means that workSatNew_r4 explains a respectable portion of the variance in satisfaction with reputation of department and institution at time t2. The other indicator variable that define satisfaction with reputation of department and institution is WorkSatNew_r5 (satisfaction with reputation of your institution) and it has the standardized factor loading of 0.696. WorkSatNew_r5 explains around 49% of the variance in satisfaction with reputation of department and institution at time t2.

TABLE XXIV. CONFIRMATORY FACTOR ANALYSIS—SATISFACTION WITH REPUTATION OF DEPARTMENT AND INSTITUTION WITH IMPUTATION

			Estimate	Std. Est.	S.E.	C.R.	P	R square
collabnom_sum	<---	Resources	1	0.596				0.356
collabintro_sum	<---	Resources	1.856	0.712	0.062	30.03	***	0.507
WorkSatNew_r4	<---	Satisfaction with reputation at t2	1	0.99				0.979
WorkSatNew_r5	<---	Satisfaction with reputation at t2	0.692	0.696	0.036	19.164	***	0.487
collabfriend_sum	<---	Strong ties	1	0.468				0.219
collabduration_sum	<---	Strong ties	2.822	0.905	0.101	27.812	***	0.818
collabgrant_sum	<---	Superior ties	1	0.737				0.543
collabsenior_sum	<---	Superior ties	1.02	0.66	0.036	28.529	***	0.436
collabfreq_sum	<---	Strong ties	1.354	0.638	0.045	30.105	***	0.407

5.9.2. Assessing model fit: SEM model predicting satisfaction with reputation of department and institution with imputation

Findings from this model suggest that RMSEA is 0.045, which indicates a good fit. Another fit index, comparative fit index (CFI) for this model is 0.92, which also indicates a good fit. However, the chi square $\chi 2$ statistic is significant which indicates that the model is rejected.

5.9.3. Direct and indirect effects: SEM model predicting satisfaction with reputation of department and institution with imputation

In this model, three of the four propositions are supported, and there is reverse support for one proposition in this model predicting satisfaction with reputation of department and institution at t2 run with imputed data. First, support is found for *P1*. Specifically, the direct effect of collaborative network constraint on superior collaborators is negative and significant (std. est. = -0.101; p value= 0.01). This finding suggests that scientists located in highly constrained collaborative network are less likely to be connected to superior collaborators in terms of seniority and grant getting ability. Next, the direct effect of strong collaborative ties on resources received from collaborators is positive and significant (std. est. =0.679; p value=0.01). This finding suggests that strong collaborative ties increase the amount of resources received by academic scientists, supporting *(P2)*. Path analysis finding showed reverse support for *P3*. Specifically, the direct effect of strong collaborative ties on superior collaborators is also positive and significant (std. est. =0.365; p value=0.01) rather than negative as was proposed in chapter 3. The positive sign means that academic scientists connected to a large number of strong collaborative ties are also connected to collaborators who are superior in terms of seniority and grant getting ability. This model also found support for *P4.* Specifically, the direct effect of superior collaborators on resources received is positive and significant (std. est. =0.194; p value=0.01). This finding indicates that scientists that are connected to a large number of superior collaborators also receive greater amounts of resources from their collaborators.

Next, among the direct effects between network factors and satisfaction with reputation of department and institution at t2, path analysis findings showed a negative and significant direct effect between collaborative network constraint at t1 and satisfaction with reputation of department and institution at t2 (std. est. =-0.095; p value=0.01). The negative direct effect of collaborative network constraint on satisfaction with reputation of department and institution suggests that academic scientists located in structurally constrained network perceive being controlled by a relatively powerful collaborator, and may form negative perceptions about themselves and their department and institution. Specifically, in collaborative exchange with a relatively powerful collaborator, the less powerful ego scientist is less able to access and control resources, perceives himself or herself to be less legitimate, and may form negative perceptions about their department and institution. Such negative perceptions may lead to lower levels of satisfaction with reputation of department and institution.

Path analysis findings also showed a negative and significant direct effect between strong collaborative ties at t1 and satisfaction with reputation of department and institution at t2 (std. est. = -0.118; p value=0.01). The negative sign suggests that having a large number of strong collaborative ties at t1 lowers satisfaction with reputation of department and institution among academic scientists at t2. Perhaps, having a large number of strong collaborative ties may create perceptions of over dependence, and incompetence, and negative perceptions of one's department and institution. Such perceptions are likely to lead to lower levels of satisfaction with reputation of department and institution.

Further, the direct effect of connections to superior collaborators at t1 on satisfaction with reputation of department and institution at t2 is negative and significant (std. est. = -0.262; p value=0.01). This negative direct effect may be explained from a social status perspective. Specifically, social status perspective argues that connection to higher status collaborators lowers the status of the ego scientist. Lower status may lead to negative perceptions about oneself and about one's department and institution, leading to lower levels of satisfaction with the reputation of department and institution. Path analysis findings showed a positive and significant direct effect of resources received from collaborators at t1 on satisfaction with reputation of department and institution at t2 (std. est. = 0.207; p value=0.01). Receiving greater amount of resources from collaborators may indicate the ego scientist is perceived to be competent, legitimate and socially valued. Specifically, when the scientists are aware that they are socially valued, it is reasonable to expect that they view their department and institution in a positive light, thereby reporting a higher level of satisfaction with reputation of their department and institution.

Path analysis findings also showed several significant direct effects between networks and rewards. For example, the direct effect of collaborative network constraint at t1 on dollar amount of grant large at t2 is positive and significant (std. est. = 0.039; p value=0.03). This positive effect suggests that academic scientists located in structurally constrained collaborative networks receive larger grants at t2. Said in another way, collaborative exchange with a relatively powerful collaborator results in large grants at t2. Negative and significant direct effect is found between connections to superior collaborative ties at t1 and reward outcomes (salary and dollar amount of largest grant) at t2. This suggests that scientists who are connected to a large number of superior collaborators in terms of seniority and grant getting ability earn lower salary at t2 as well as receive smaller grants in terms of dollar amounts. Specifically, connections to large number of superior collaborators in terms of seniority and grant getting ability at t1 tend to reduce both reward outcomes at t2. Perhaps, this negative direct effect may be explained from a social status perspective. Specifically, connection to higher status collaborators lowers the status of the ego scientist. Ego scientists of lower status may be less likely to access and control resources essential to achieve rewards and professional recognition.

Several positive and significant direct effects were also found between networks and rewards. For example, the direct effect of being connected to a large number of strong collaborative ties on both reward outcomes (salary and dollar amount of largest grant) is positive and significant. Specifically, academic scientists connected to a large number of strong collaborative ties at t1 achieve higher levels of rewards at t2. When scientists engage in collaborative exchange with strong ties, they offer their knowledge to their strong collaborative ties and in turn receive greater levels of rewards and professional recognition because strong collaborative ties are reciprocal in nature.

Path analysis findings showed that reward outcomes are unrelated to satisfaction with reputation of their department and institution. Among the relationships between non network and demographic control variables and satisfaction with reputation of department and institution, the findings are very similar to the previous model. For example, the scientists who are located in department with large number of faculty report higher satisfaction with reputation of their department and institution. Further, scientists who publish more report a higher level of satisfaction with reputation of their department and institution. Scientists who teach or co teach greater number of resources report a lower level of satisfaction with reputation of their department and institution. Associate professors are less satisfied with reputation of their department and institution compared to full professors. Women scientists are less satisfied with reputation of their department and institution compared to men. Earth and environmental scientists, computer scientists, and electrical engineers are more satisfied with reputation of their department and institution compared to biologists. South or south East Asian scientists and African American scientists are more satisfied with reputation of their department and institution compared to whites.

This model predicting satisfaction with reputation of department and institution with imputed data found several indirect effects. For example, several significant indirect effects were found between collaborative network factors and reward outcomes, as well as between collaborative network factors and satisfaction with reputation of department and institution. For example, the indirect effect of collaborative network constraint on both reward outcomes is positive and significant. This means that as constraint in scientist's collaborative network increases, rewards also increase through the effect of constraint on the intervening variable. The intervening variable in this case is superior collaborative ties. Another positive and significant indirect effect was found between connections to superior collaborators and salary, and the size of this effect will increase when resources received from collaborators increases. While the indirect effect of constraint on reward outcomes is positive, the indirect effect of strong collaborative ties on both reward outcomes (salary, and dollar amount of largest grant) is negative and significant. This means that as the number of strong collaborative ties increase, rewards decrease through the effect of strong collaborative ties on the intervening variables.

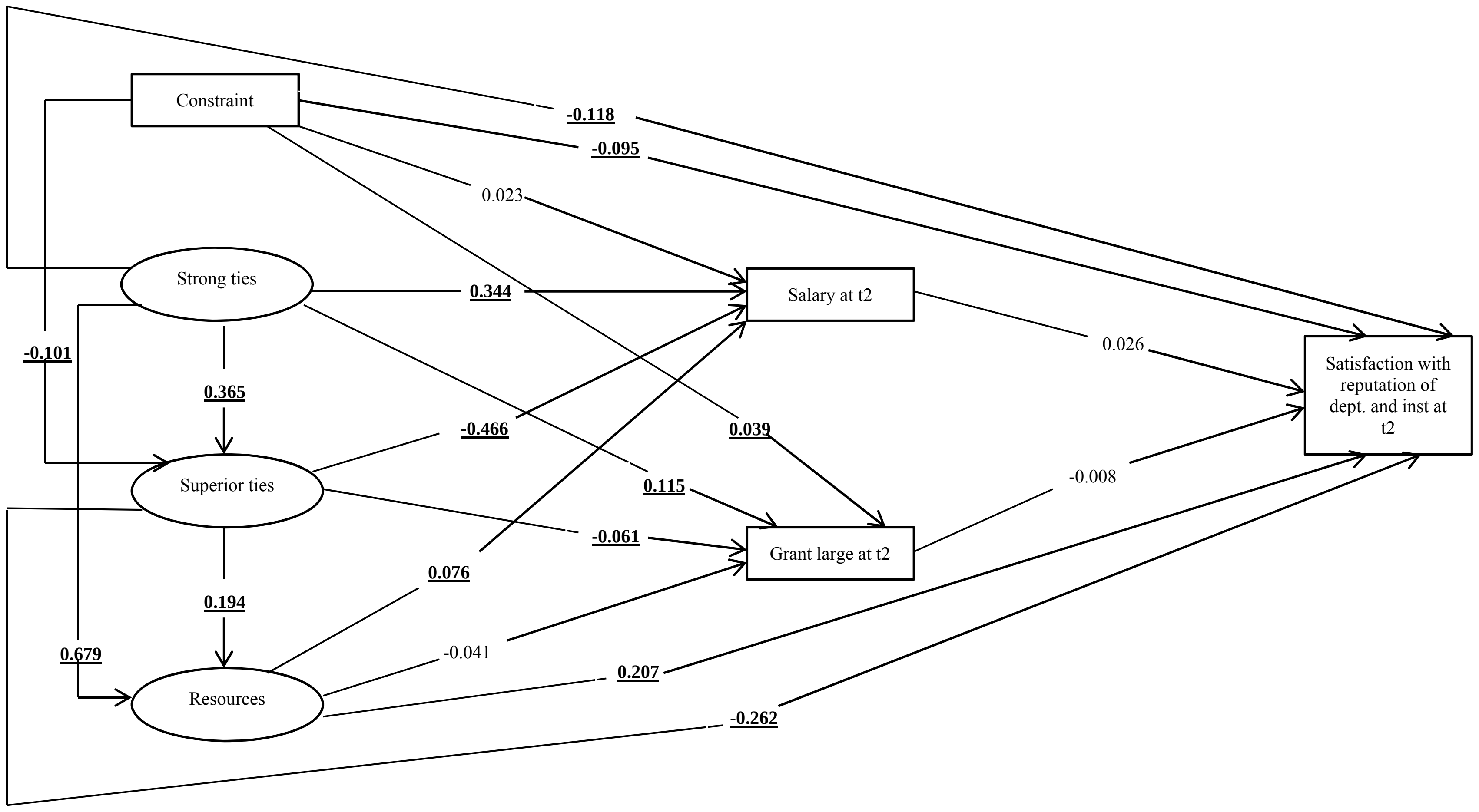
Turning to the indirect effect between collaborative network and satisfaction with reputation of department and institution, path analysis showed several indirect effects. For example, the indirect effect of collaborative network at t1 on satisfaction with reputation of department and institution at t2 through the mediating influence of intervening variables is positive and significant (std. est. = 0.024; p value=0.01). However, this finding does not indicate support for H1 as the two reward outcomes—salary and dollar amount of largest grant are unrelated to satisfaction with reputation of department and institution. In other words, the indirect effect of collaborative network constraint on satisfaction with reputation of department and institution through the mediating influence of rewards and recognition is not statistically supported. Next, the indirect effect of strong collaborative ties on satisfaction with reputation of department and institution through the mediating influence of rewards and recognition is also not statistically supported. Although, the indirect effect of strong collaborative ties on satisfaction with reputation of department and institution through the mediating influence of all the intervening variables is positive and significant.

Further, the indirect effect of connections to superior collaborators at t1 on satisfaction with reputation of department and institution at t2 is positive and significant (std. est. = 0.029; p value= 0.05). However, this finding does not indicate support for H3a as the two reward outcomes—salary and dollar amount of largest grant are unrelated to satisfaction with reputation of department and institution. In other words, the indirect effect of connections to superior collaborators on satisfaction with reputation of department and institution through the mediating influence of rewards and recognition is not statistically supported.

5.9.4. Summary of findings of the above structural equation model predicting satisfaction with reputation of department and institution run with imputation

The main finding of this model is that the indirect effects of the four collaborative network properties through the mediating influence of rewards and recognition (salary, and dollar amount of largest grant) on satisfaction with reputation of department and institution are not significant. For the indirect effect of collaborative networks on satisfaction with reputation of department and institution through the mediating influence of rewards and recognition to be significant, salary and dollar amount of largest grant have to be statistically related to satisfaction with reputation of department and institution. However, salary and dollar amount of largest grant are not related to satisfaction with reputation of department and institution.

Fig 19. Direct paths (standardized estimates): model predicting satisfaction with reputation of department and institution at t2 (with weights and with imputation)



- **Estimates that are significant are in bold**
- **Controls are not shown for the sake of clarity**

TABLE XXV. TOTAL, DIRECT, AND INDIRECT EFFECTS (SATISFACTION WITH REPUTATION OF DEPARTMENT AND INSTITUTION WITH IMPUTATION)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint--->superior ties	-0.101	0.015	0.01	-0.101	0.015	0.01	...	...	...
	Constraint--->resources	-0.02	0.004	0.01	...	...	...	-0.02	0.004	0.01
	Constraint--->salary at t2	0.069	0.013	0.01	0.023	0.014	0.122	0.046	0.007	0.01
	Constraint--->grant large at t2	0.046	0.015	0.01	0.039	0.015	0.03	0.007	0.003	0.01
H1	Constraint--->satisfaction with reputation of dept. and inst at t2	-0.071	0.02	0.01	-0.095	0.02	0.01	0.024	0.005	0.01
P3	Strong ties-->superior ties	0.365	0.019	0.01	0.365	0.019	0.01	...	...	...
P2	Strong ties--->resources	0.749	0.016	0.01	0.679	0.02	0.01	0.071	0.009	0.01
	Strong ties--->salary at t2	0.23	0.015	0.01	0.344	0.035	0.01	-0.113	0.032	0.01
	Strong ties--->grant large at t2	0.063	0.017	0.01	0.115	0.034	0.01	-0.052	0.027	0.042
H2a, H2b	Strong ties--->satisfaction with reputation of dept. and inst at t2	-0.053	0.02	0.02	-0.118	0.035	0.01	0.065	0.031	0.036
P4	Superior ties--->resources	0.194	0.023	0.01	0.194	0.023	0.01	...	...	...
	Superior ties--->salary at t2	-0.451	0.017	0.01	-0.466	0.018	0.01	0.015	0.009	0.077
	Superior ties--->grant large at t2	-0.068	0.022	0.01	-0.061	0.024	0.016	-0.008	0.007	0.253
H3a, H3b	Superior ties--->satisfaction with reputation of dept. and inst at t2	-0.233	0.027	0.01	-0.262	0.034	0.01	0.029	0.014	0.052
	Resources--->salary at t2	0.076	0.042	0.076	0.076	0.042	0.076	...	...	...
	Resources--->grant large at t2	-0.041	0.039	0.253	-0.041	0.039	0.253	...	...	...
H4	Resources--->satisfaction with reputation of dept. and inst at t2	0.21	0.041	0.01	0.207	0.041	0.01	0.002	0.002	0.344
	Salary at t2--->satisfaction with reputation of dept. and inst at t2	0.026	0.021	0.209	0.026	0.021	0.209	...	...	...
	Grant large at t2--->satisfaction with reputation of dept. and inst at t2	-0.008	0.015	0.712	-0.008	0.015	0.712	...	...	...
	Receipt of organizational resources--->satisfaction with reputation of dept. and inst at t2	-0.006	0.016	0.771	-0.006	0.016	0.771	...	...	...
	Number of publications at t1--->satisfaction with reputation of dept. and inst at t2	0.05	0.019	0.01	0.05	0.019	0.01	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with reputation of dept. and inst at t2	-0.039	0.016	0.051	-0.039	0.016	0.051	...	...	...
	Dept faculty size--->satisfaction with reputation of dept. and inst at t2	0.118	0.016	0.01	0.118	0.016	0.01	...	...	...
	Female--->satisfaction with reputation of dept. and inst at t2	-0.032	0.016	0.056	-0.032	0.016	0.056	...	...	...
	South or southeast asian--->satisfaction with reputation of dept. and inst at t2	0.039	0.014	0.014	0.039	0.014	0.014	...	...	...
	Black/African American--->satisfaction with reputation of dept. and inst at t2	0.032	0.013	0.013	0.032	0.013	0.013	...	...	...
	Hispanic--->satisfaction with reputation of dept. and inst at t2	0.017	0.017	0.285	0.017	0.017	0.285	...	...	...
	Assistant Professor--->satisfaction with reputation of dept. and inst at t2	-0.013	0.025	0.723	-0.013	0.025	0.723	...	...	...
	Associate Professor--->satisfaction with reputation of dept. and inst at t2	-0.055	0.017	0.01	-0.055	0.017	0.01	...	...	...
	Physics--->satisfaction with reputation of dept. and inst at t2	0.007	0.019	0.703	0.007	0.019	0.703	...	...	...
	Chemistry--->satisfaction with reputation of dept. and inst at t2	0.014	0.018	0.398	0.014	0.018	0.398	...	...	...
	EAS-->satisfaction with reputation of dept. and inst at t2	0.144	0.017	0.01	0.144	0.017	0.01	...	...	...
	CS--->satisfaction with reputation of dept. and inst at t2	0.055	0.019	0.01	0.055	0.019	0.01	...	...	...
	EE--->satisfaction with reputation of dept. and inst at t2	0.042	0.02	0.04	0.042	0.02	0.04	...	...	...

5.10. Summary of the overall SEM findings

The previous sections presented and discussed the findings from four SEM models. Two models predicting satisfaction with rewards at t2 were run with and without imputing for missing data. Similarly, two models predicting satisfaction with reputation of department and institution at t2 were run with and without imputing for missing data. Findings from the four SEM models showed support for several propositions and hypotheses. Additionally, direct and indirect effects of collaborative network on reward outcomes, effect of non-network, and demographic control variables on satisfaction, as well as the effect of reward outcomes on satisfaction were discussed. In this section, a summary of findings from all the four models is presented (see tables 20 and 21). A comparison of path analysis findings between satisfaction with rewards and satisfaction with reputation of department and institution is also presented.

First, both models (without and with imputation) predicting satisfaction with rewards at t2 showed support for two propositions *P1* and *P2*. Specifically, the direct effect of collaborative network constraint on superior collaborators was found to be negative and significant *(P1)* in both models. The direct effect of strong collaborative ties on resources received from collaborators was positive and significant *(P2)* in both models. Path analysis findings showed reverse support for *P3*. Specifically, it was proposed that strong collaborative ties would be negatively related to satisfaction, however, the findings showed positive relationship (see figures 6 and 7, and tables 10 and 14). In summary, scientists that are situated in constrained collaborative networks are less likely to be connected to collaborators who are senior and who have a better grant getting ability. Further, scientists that are connected to a large number of strong collaborative ties are more likely to receive greater amount of resources because strong ties may be more motivated to provide resources. Lastly, scientists that are connected to a large number of strong collaborative ties are connected to collaborators who are superior in terms of seniority and grant getting ability.

Second, both models (without and with imputation) predicting satisfaction with rewards at t2 showed support for H1, H2a, H3b, and H4 (see figures 6 and 7, and tables 10 and 14). Specifically, the indirect effect of collaborative network constraint on satisfaction with rewards was found to be negative and significant (H1). This finding means that scientists engaged in collaborative exchange with a relatively powerful collaborator report lower levels of satisfaction with rewards. The structurally powerful collaborator may be ***controlling***, and may withhold rewards and professional recognition from the scientist, and hence the scientist repots a lower level of satisfaction with rewards. The direct effect of collaborative network constraint on satisfaction with rewards is also negative and significant suggesting that scientist may perceive himself to be socially controlled, less valued, and less ***legitimate***, and may form negative perceptions about ones abilities resulting in lower levels of satisfaction. Next, the indirect effect of strong collaborative ties on satisfaction with rewards was found to be positive and significant (H2a). This finding suggests that strong collaborative ties because of their ***reciprocal*** nature provide greater rewards and recognition, and consequently greater levels of satisfaction with rewards. Interestingly, the direct effect of strong collaborative ties on satisfaction with rewards is negative and significant, which suggests that having a large number of strong collaborative ties may create perceptions of over dependence, incompetence, or lack of sense of control over ones work. Such perceptions lead to lower levels of satisfaction with rewards. Further, the indirect effect of connections to superior collaborators on satisfaction with rewards was found to be negative and significant (H3b). The negative indirect effect indicates that scientists connected to a large number of superior collaborators may not able to convert those connections to rewards, and hence report a lower level of satisfaction with rewards. Interestingly, the direct effect of collaborative network constraint on satisfaction with rewards is positive and significant. The positive direct effect and negative indirect effect of connections to superior collaborators on satisfaction with rewards may suggest that the ***validation and legitimacy*** benefits accruing from connections to superior collaborators enhances self-esteem and positive perceptions about one's ability, however connections to superior collaborators may not result in rewards and recognition, and as a result, the scientist reports a lower level of satisfaction with rewards. Lastly, the indirect effect of resources received from collaborators on satisfaction with rewards was found to be positive and significant (H4). This finding means that scientists that receive greater amount of resources from their collaborators earn greater ***legitimacy,*** and are able to convert those resources to rewards, and in turn report a higher level of satisfaction with rewards. The direct effect of resources received from collaborators on satisfaction with rewards is also positive and significant. A summary of the SEM findings are presented in tables 20 and 21.

Turning to the SEM findings for the two models predicting satisfaction with reputation of department and institution, one finds support for three propositions *P1*, *P2*, and *P4* in the model run with imputed data. Similar to the satisfaction with rewards model, path analysis findings showed reverse support for *P3* in both models predicting satisfaction with reputation of department and institution at t2 (without and with imputed data). In summary, scientists that are situated in constrained collaborative networks are less likely to be connected to collaborators who are senior and who have a better grant getting ability *(P1).* Further, scientists that are connected to a large number of strong collaborative ties are more likely to receive greater amount of resources because strong ties may be more motivated to provide resources *(P2).* Next, scientists that are connected to a large number of strong collaborative ties are also connected to collaborators who are superior in terms of seniority and grant getting ability *(reverse support for P3).* Specifically, it was proposed that strong collaborative ties would be negatively related to superior collaborators, however, the findings showed positive relationship. Lastly, in the model run with imputed data, it was found that scientists that are connected to a large number of superior collaborators receive greater amount of resources *(P4).*

The models predicting satisfaction with reputation of department and institution did not find statistical support for any of the hypotheses. Specifically, the indirect effects of the four collaborative network properties through the mediating influence of rewards and recognition (salary, and dollar amount of largest grant) on satisfaction with reputation of department and institution are not significant. For the indirect effect of collaborative networks on satisfaction with reputation of department and institution through the mediating influence of rewards and recognition to be significant, salary and dollar amount of largest grant have to be statistically related to satisfaction with reputation of department and institution. The lack of statistical support for the hypotheses in the satisfaction with reputation models indicate that rewards such as salary and dollar amount of largest grant do not have a role to play in determining satisfaction with reputation of department and institution. Perhaps other forms of rewards and recognition may work for satisfaction with reputation of department and institution.

Satisfaction with rewards and satisfaction with reputation represent two entirely different aspects of satisfaction. Satisfaction with rewards may represent satisfaction with one's own professional recognition, and satisfaction with reputation of department and institution may represent scientist's perception or image of their department and institution. Satisfaction with reputation of department and institution represents a broader view of satisfaction. Because, these two kinds of satisfaction represent different aspects, their network determinants may also be different. Similarly, their reward and recognition determinants may also be different.

Specifically, the collaborative network properties through the mediating influence of rewards and recognition that positively predict satisfaction with rewards, may not predict satisfaction with reputation of department and institution.

TABLE XXVI. SUMMARY OF FINDINGS (PROPOSITIONS AND HYPOTHESES) FOR SATISFACTION WITH REWARDS AT T2 AND SATISFACTION WITH REPUTATION OF DEPARTMENT AND INSTITUTION AT T2

	Satisfaction with rewards		Satisfaction with reputation of dept and inst	
Propositions and Hypotheses	**w/o imputation**	**imputation**	**w/o imputation**	**imputation**
P1: *Network constraint will be negatively related to number of superior collaborators*	S	S	S	S
P2 **:** *The number of strong ties will be positively related to resources received*	S	S	S	S
P3: *The number of strong ties will be negatively related to the number of superior collaborators*	RS	RS	RS	RS
P4: *The number of superior collaborators will be positively associated with resources received*	N	N	N	S
H1: Collaborative network constraint will be negatively related to satisfaction of academic scientists.	S	S	N	N
H2a: Scientists with a greater number of strong collaborative ties will report higher levels of satisfaction	S	S	N	N
H2b: Scientists with a greater number of strong collaborative ties will report lower levels of satisfaction			N	N
H3a: Scientists with greater number of superior collaborators will report higher levels of satisfaction			N	N
H3b: Scientists with greater number of superior alters in their collaborative network will report lower leve	S	S	N	N
H4: Scientists that receive more resources from their collaborative networks will report higher levels of s	S	S	N	N

S: supported; RS: reverse support; N: not supported

TABLE XXVII. SUMMARY OF OTHER FINDINGS FOR SATISFACTION WITH REWARDS AT T2 AND SATISFACTION WITH REPUTATION OF DEPARTMENT AND INSTITUTION AT T2

	Satisfaction with rewards				Satisfaction with reputation of dept. and inst.			
	without imputation		with imputation		without imputation		with imputation	
	direct	indirect	direct	indirect	direct	indirect	direct	indirect
constraint--->resources	NA	N	NA	NEG	NA	NEG	NA	NEG
constraint --->salary at t2	NEG	POS	NEG	POS	NEG	POS	N	POS
constraint--->grant large at t2	N	POS	POS	POS	POS	POS	POS	POS
strong ties--->salary at t2	POS	N	POS	NEG	POS	NEG	POS	NEG
strong ties--->grant large at t2	POS	NEG	POS	NEG	POS	NEG	POS	NEG
superior ties-->salary at t2	NEG	N	NEG	POS	NEG	N	NEG	POS
superior ties-->grant large at t2	NEG	N	NEG	N	NEG	N	NEG	N
resources-->salary at t2	POS	NA	POS	NA	N	NA	POS	NA
resources-->grant large at t2	N	NA	N	NA	N	NA	N	NA
salary at t2-->satisfaction with rewards at t2	POS	NA	POS	NA	N	NA	N	NA
grant large at t2-->satisfaction with rewards at t2	NEG	NA	NEG	NA	N	NA	N	NA

POS: Positive; NEG: Negative; N:not supported; NA: not applicable

6. Additional SEM efforts

The previous section presented and discussed structural equation model findings for four models. The first two models were run for satisfaction with rewards, without and with imputed data and the last two were run for satisfaction with reputation of department and institution, without and with imputed data. In this section, a brief discussion of SEM models run in addition to the previous four models is presented.

Additional models predicting satisfaction with rewards at t2, and satisfaction with reputation of department and institution at t2 were run controlling for satisfaction with rewards at t1, and satisfaction with reputation of department and institution at t1 respectively (see tables 1and 2 in the appendix at the end of the dissertation). However, there was no substantive difference between the models run with and without satisfaction at t1 variable[4]. Structural equation models were also run without weights (see tables 3 through 10 in the appendix at the end of the dissertation). Other structural equation models in which rewards and recognition at time t1 mediate the relationship between collaborative networks and satisfaction are also run (see tables 22 through 25). A brief discussion of the findings from these models is presented below.

6.1. Structural equation model findings predicting satisfaction with rewards at t2, with rewards and awards at t1

This section presents and discusses findings from structural equation model in which rewards and rewards at time t1 mediate the relationship between collaborative networks at time t1 and satisfaction with rewards at t2. Findings from this model show support for *P1* and *P2,* and reverse support for *P3* and *P4.* In other words, the findings suggest that scientists with higher constraint in their collaborative network have fewer superior collaborators in their network (*P1*). Next, scientists that have a large number of strong collaborative ties receive greater amount of resources from their collaborators *(P2)*. Further, reverse support was found for *P3.* Specifically, a negative relationship was expected between strong ties and superior ties, however, findings showed a positive relationship. In other words, scientists who have a large number of strong collaborative ties also have a large number of superior collaborators in terms of seniority and grant getting ability. These above three findings are similar to the earlier models in which

[4] Tables 1 and 2 are situated at the end of the chapters in the appendix as there are no substantial differences between these two models and the models presented in chapter 5.

rewards at t2 mediated the relationship between collaborative networks and satisfaction. Interestingly, in this model, reverse support was indicated for *P4.* Specifically, a positive relationship was expected between superior collaborative ties and resources received from collaborators, however, findings showed a negative relationship. In other words, scientists who have a large number of superior collaborative ties receive fewer resources.

Next, among the total, direct, and indirect effects between collaborative network factors and satisfaction with rewards at t2, path analysis findings showed a negative and significant total and direct effect, and a positive indirect effect between strong collaborative ties at t1 and satisfaction with rewards at t2. The negative direct effect and positive indirect effect of strong collaborative ties on satisfaction with rewards may suggest that it is through the effects of other intervening collaborative network variables that strong collaborative ties are able to lead to higher level of satisfaction with rewards. It is important to note that awards are unrelated to satisfaction with rewards, so the indirect effect of strong collaborative ties on satisfaction with rewards does not occur through awards. Further, path analysis findings showed a positive direct effect and negative indirect effect of superior collaborative ties at t1 on satisfaction with rewards at t2. This finding may suggest that although having a large number of superior collaborative creates enhances self-esteem of academic scientists, and leads to positive evaluation of one's ability to achieve rewards and professional recognition, however being connected to superior collaborators is not able to lead to rewards and awards, and consequently leads to lower levels of satisfaction with rewards. Path analysis findings showed that total, direct and indirect effects of resources received from collaborators at time t1 on satisfaction with rewards at time t2 is positive and significant. Again, the indirect effect of resources received on satisfaction with rewards does not necessarily occur through awards as awards is unrelated to satisfaction with rewards.

Turning to the path analysis findings on the direct effects between rewards and awards at t1 and satisfaction with rewards at time t2 indicate that salary at t1 has a positive and significant direct effect on satisfaction with rewards at t2. This finding suggests that scientists who earn higher salary also report a higher a higher level of satisfaction with rewards. Said in another way, higher salary leads to fulfillment of reward expectations resulting in higher levels of satisfaction with rewards. However, the other reward outcome—dollar amount of largest grant has a negative and significant effect on satisfaction with rewards. Perhaps, receiving large grants from external agencies may not result in fulfillment of reward expectations. Awards at t1 have no effect on satisfaction with rewards at t2.

6.2. Structural equation model findings predicting satisfaction with reputation of department and institution at t2, with rewards and awards at t1

This section presents and discusses findings from structural equation model in which rewards and rewards at time t1 mediate the relationship between collaborative networks at time t1 and satisfaction with reputation of department and institution at t2. Findings from this model, as in the previous model also show support for *P1* and *P2,* and reverse support for *P3* and *P4.*

Next, among the total, direct, and indirect effects between collaborative network factors and satisfaction with reputation of department and institution at t2, path analysis findings showed a negative and significant total and direct effect, and a positive indirect effect between collaborative network constraint at t1 and satisfaction with reputation of department and institution at t2. The positive indirect effect indicates that collaborative network constraint leads to changes in the intervening variables, which in turn lead to change in satisfaction with reputation of department and institution, and this change is positive and significant. It is important to note here that this indirect effect does not occur through reward and awards. The negative direct effect suggests that collaborative exchange with a relatively powerful collaborator within a constrained network creates negative perceptions about the department and institution. Since the total and direct effect of collaborative network constraint on satisfaction with reputation of department and institution is negative and significant, there is little evidence for complete mediation of the intervening variables. Other indirect effects of collaborative networks on satisfaction with reputation of department and institution are not found to be significant.

Turning to the path analysis findings on the direct effects between rewards and awards at t1 and satisfaction with reputation of department and institution at time t2 indicate that salary at t1 has a positive and significant direct effect on satisfaction with reputation of department and institution at t2. This finding suggests that scientists who earn higher salary also report a higher a higher level of satisfaction with reputation of department and institution. Said in another way, higher salary leads to fulfillment of expectations regarding the reputation of department and institution. However, dollar amount of largest grant has a negative and significant effect on satisfaction with reputation of department and institution. Perhaps, receiving large grants from external agencies may not result in fulfillment of expectations regarding the reputation of department and institution. Awards at t1 have a positive effect on satisfaction with reputation of department and institution at t2.

TABLE XXVIII. TOTAL, DIRECT, AND INDIRECT EFFECTS (SATISFACTION WITH REWARDS MODEL WITH WEIGHTS, WITH REWARDS AND AWARDS AT T1 AND WITHOUT SATISFACTION WITH REWARDS AT T1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**
P1	Constraint--->superior ties	-0.09	0.019	0.01	-0.09	0.019	0.01	...	...	...
	Constraint--->resources	0.036	0.01	0.01	...	0	...	0.036	0.01	0.01
	Constraint--->awards at t1	-0.004	0.018	0.92	-0.01	0.018	0.741	0.006	0.003	0.103
	Constraint--->salary at t1	0.032	0.016	0.028	-0.015	0.017	0.45	0.047	0.009	0.01
	Constraint--->grant large at t1	-0.087	0.018	0.01	-0.093	0.018	0.01	0.006	0.005	0.157
H1	Constraint--->satisfaction with rewards at t2	-0.016	0.023	0.547	-0.021	0.026	0.429	0.006	0.009	0.378
P3	Strong ties-->superior ties	0.351	0.023	0.01	0.351	0.023	0.01	...	...	...
P2	Strong ties--->resources	0.79	0.027	0.01	0.931	0.064	0.01	-0.141	0.058	0.01
	Strong ties--->awards at t1	0.122	0.021	0.01	0.101	0.067	0.051	0.021	0.059	0.725
	Strong ties--->salary at t1	0.052	0.019	0.01	0.044	0.052	0.279	0.008	0.045	0.978
	Strong ties--->grant large at t1	-0.017	0.019	0.302	0.136	0.065	0.01	-0.153	0.062	0.01
H2a, H2b	Strong ties--->satisfaction with rewards at t2	-0.106	0.028	0.01	-0.243	0.142	0.01	0.137	0.128	0.01
P4	Superior ties--->resources	-0.402	0.153	0.01	-0.402	0.153	0.01	...	...	...
	Superior ties--->awards at t1	-0.069	0.037	0.104	-0.05	0.031	0.104	-0.019	0.032	0.448
	Superior ties--->salary at t1	-0.528	0.041	0.01	-0.445	0.022	0.01	-0.083	0.035	0.01
	Superior ties--->grant large at t1	-0.068	0.043	0.158	-0.124	0.027	0.01	0.056	0.043	0.01
H3a,H3b	Superior ties--->satisfaction with rewards at t2	-0.031	0.096	0.586	0.099	0.051	0.067	-0.13	0.075	0.01
	Resources--->awards at t1	0.048	0.065	0.448	0.048	0.065	0.448	...	...	...
	Resources--->salary at t1	0.208	0.048	0.01	0.208	0.048	0.01	...	...	...
	Resources--->grant large at t1	-0.139	0.065	0.01	-0.139	0.065	0.01	...	...	...
H4	Resources--->satisfaction with rewards at t2	0.157	0.137	0.01	0.114	0.141	0.098	0.044	0.01	0.015
	Awards at t1--->satisfaction with rewards at t2	0.025	0.018	0.173	0.025	0.018	0.173	...	...	...
	Salary at t1--->satisfaction with rewards at t2	0.164	0.024	0.01	0.164	0.024	0.01	...	...	...
	Grant large at t1--->satisfaction with rewards at t2	-0.061	0.023	0.02	-0.061	0.023	0.02	...	...	...
	Receipt of organizational resources--->satisfaction with rewards at t2	0.064	0.02	0.01	0.064	0.02	0.01	...	...	...
	Number of publications at t1--->satisfaction with rewards at t2	0.000	0.025	0.951	0.000	0.025	0.951	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with rewards at t2	0.015	0.019	0.435	0.015	0.019	0.435	...	...	...
	Dept faculty size--->satisfaction with rewards at t2	0.028	0.02	0.189	0.028	0.02	0.189	...	...	...
	Female--->satisfaction with rewards at t2	-0.089	0.021	0.01	-0.089	0.021	0.01	...	...	...
	South or southeast asian--->satisfaction with rewards at t2	0.009	0.019	0.587	0.009	0.019	0.587	...	...	...
	Black/African American--->satisfaction with rewards at t2	0.078	0.019	0.01	0.078	0.019	0.01	...	...	...
	Hispanic--->satisfaction with rewards at t2	0.007	0.018	0.779	0.007	0.018	0.779	...	...	...
	Assistant Professor--->satisfaction with rewards at t2	-0.092	0.046	0.029	-0.092	0.046	0.029	...	...	...
	Associate Professor--->satisfaction with rewards at t2	-0.124	0.027	0.01	-0.124	0.027	0.01	...	...	...
	Physics--->satisfaction with rewards at t2	-0.072	0.026	0.013	-0.072	0.026	0.013	...	...	...
	Chemistry--->satisfaction with rewards at t2	-0.08	0.037	0.01	-0.08	0.037	0.01	...	...	...
	EAS-->satisfaction with rewards at t2	-0.001	0.028	0.924	-0.001	0.028	0.924	...	...	...
	CS--->satisfaction with rewards at t2	0.007	0.025	0.779	0.007	0.025	0.779	...	...	...
	EE--->satisfaction with rewards at t2	-0.091	0.026	0.01	-0.091	0.026	0.01	...	...	...

TABLE XXIX. TOTAL, DIRECT, AND INDIRECT EFFECTS (SATISFACTION WITH REWARDS MODEL WITH WEIGHTS, WITH REWARDS AND AWARDS AT T1 AND WITH SATISFACTION WITH REWARDS AT T1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint--->superior ties	-0.087	0.021	0.01	-0.087	0.021	0.01	…	…	…
	Constraint--->resources	0.039	0.013	0.031	…	…	…	0.039	0.013	0.031
	Constraint--->awards at t1	0.001	0.016	0.91	-0.007	0.017	0.627	0.008	0.004	0.043
	Constraint--->salary at t1	0.047	0.015	0.013	-0.005	0.017	0.84	0.052	0.01	0.01
	Constraint--->grant large at t1	-0.088	0.02	0.01	-0.095	0.02	0.01	0.006	0.005	0.187
H1	Constraint--->satisfaction with rewards at t2	0.007	0.018	0.619	0	0.021	0.903	0.007	0.008	0.325
P3	Strong ties-->superior ties	0.359	0.023	0.01	0.359	0.023	0.01	…	…	…
P2	Strong ties--->resources	0.786	0.023	0.01	0.948	0.087	0.01	-0.162	0.088	0.032
	Strong ties--->awards at t1	0.129	0.02	0.01	0.093	0.06	0.1	0.036	0.054	0.486
	Strong ties--->salary at t1	0.047	0.018	0.02	0	0.052	0.962	0.046	0.048	0.292
	Strong ties--->grant large at t1	-0.018	0.021	0.435	0.131	0.052	0.01	-0.149	0.047	0.01
H2a, H2b	Strong ties--->satisfaction with rewards at t2	-0.146	0.022	0.01	-0.413	0.065	0.01	0.267	0.054	0.01
P4	Superior ties--->resources	-0.451	0.227	0.032	-0.451	0.227	0.032	…	…	…
	Superior ties--->awards at t1	-0.088	0.039	0.043	-0.056	0.031	0.085	-0.032	0.03	0.286
	Superior ties--->salary at t1	-0.595	0.064	0.01	-0.471	0.021	0.01	-0.124	0.059	0.032
	Superior ties--->grant large at t1	-0.071	0.05	0.187	-0.13	0.025	0.01	0.059	0.05	0.032
H3a,H3b	Superior ties--->satisfaction with rewards at t2	-0.063	0.1	0.369	0.012	0.047	0.783	-0.075	0.082	0.19
	Resources--->awards at t1	0.072	0.061	0.256	0.072	0.061	0.256	…	…	…
	Resources--->salary at t1	0.274	0.048	0.01	0.274	0.048	0.01	…	…	…
	Resources--->grant large at t1	-0.131	0.052	0.01	-0.131	0.052	0.01	…	…	…
H4	Resources--->satisfaction with rewards at t2	0.307	0.061	0.01	0.341	0.064	0.01	-0.034	0.012	0.01
	Awards at t1--->satisfaction with rewards at t2	0.004	0.018	0.75	0.004	0.018	0.75	…	…	…
	Salary at t1--->satisfaction with rewards at t2	-0.131	0.029	0.01	-0.131	0.029	0.01	…	…	…
	Grant large at t1--->satisfaction with rewards at t2	-0.011	0.017	0.543	-0.011	0.017	0.543	…	…	…
	Receipt of organizational resources--->satisfaction with rewards at t2	-0.038	0.016	0.032	-0.038	0.016	0.032	…	…	…
	Number of publications at t1--->satisfaction with rewards at t2	0.029	0.021	0.178	0.029	0.021	0.178	…	…	…
	Number of courses taught or co taught at t1--->satisfaction with rewards at t2	0.007	0.018	0.711	0.007	0.018	0.711	…	…	…
	Dept faculty size--->satisfaction with rewards at t2	-0.079	0.018	0.01	-0.079	0.018	0.01	…	…	…
	Female--->satisfaction with rewards at t2	-0.047	0.018	0.01	-0.047	0.018	0.01	…	…	…
	South or southeast asian--->satisfaction with rewards at t2	0.03	0.016	0.067	0.03	0.016	0.067	…	…	…
	Black/African American--->satisfaction with rewards at t2	0.057	0.017	0.01	0.057	0.017	0.01	…	…	…
	Hispanic--->satisfaction with rewards at t2	-0.005	0.015	0.795	-0.005	0.015	0.795	…	…	…
	Assistant Professor--->satisfaction with rewards at t2	-0.164	0.034	0.01	-0.164	0.034	0.01	…	…	…
	Associate Professor--->satisfaction with rewards at t2	-0.149	0.022	0.01	-0.149	0.022	0.01	…	…	…
	Physics--->satisfaction with rewards at t2	-0.031	0.023	0.138	-0.031	0.023	0.138	…	…	…
	Chemistry--->satisfaction with rewards at t2	-0.084	0.027	0.01	-0.084	0.027	0.01	…	…	…
	EAS-->satisfaction with rewards at t2	-0.01	0.021	0.791	-0.01	0.021	0.791	…	…	…
	CS--->satisfaction with rewards at t2	0.004	0.023	0.808	0.004	0.023	0.808	…	…	…
	EE--->satisfaction with rewards at t2	-0.039	0.021	0.07	-0.039	0.021	0.07	…	…	…
	Satisfaction with rewards at t1--->satisfcation with rewards at t2	0.705	0.02	0.01	0.705	0.02	0.01			

TABLE XXX. TOTAL, DIRECT, AND INDIRECT EFFECTS (SATISFACTION WITH REPUTATION MODEL WITH WEIGHTS, WITH REWARDS AND AWARDS AT T1 AND WITHOUT SATISFACTION WITH REPUTATION AT T1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint at t1--->superior ties at t1	-0.087	0.02	0.01	-0.087	0.02	0.01	...	...	...
	Constraint at t1--->resources at t1	0.024	0.007	0.01	...	...	...	0.024	0.007	0.01
	Constraint at t1--->awards at t1	-0.014	0.016	0.337	-0.015	0.016	0.317	0.001	0.004	0.942
	Constraint at t1--->salary at t1	0.012	0.017	0.493	-0.024	0.017	0.096	0.036	0.009	0.01
	Constraint at t1--->grant large at t1	-0.08	0.017	0.01	-0.079	0.018	0.01	-0.002	0.005	0.863
H1	Constraint at t1--->satisfaction with reputation of dept. and inst at t2	-0.046	0.032	0.151	-0.059	0.031	0.052	0.013	0.007	0.038
P3	Strong ties at t1-->superior ties at t1	0.38	0.03	0.01	0.38	0.03	0.01	...	...	...
P2	Strong ties at t1--->resources at t1	0.855	0.041	0.01	0.962	0.049	0.01	-0.107	0.039	0.01
	Strong ties at t1--->awards at t1	0.152	0.021	0.01	0.102	0.099	0.136	0.05	0.091	0.564
	Strong ties at t1--->salary at t1	0.145	0.021	0.01	0.417	0.122	0.01	-0.272	0.118	0.01
	Strong ties at t1--->grant large at t1	0.024	0.024	0.428	0.343	0.158	0.01	-0.319	0.158	0.01
H2a, H2b	Strong ties at t1--->satisfaction with reputation of dept. and inst at t2	-0.079	0.12	0.19	-0.159	1.279	0.348	0.08	1.171	0.515
P4	Superior ties at t1--->resources at t1	-0.282	0.097	0.01	-0.282	0.097	0.01	...	...	...
	Superior ties at t1--->awards at t1	-0.01	0.048	0.942	0.005	0.034	0.82	-0.016	0.026	0.585
	Superior ties at t1--->salary at t1	-0.41	0.041	0.01	-0.444	0.028	0.01	0.034	0.035	0.201
	Superior ties at t1--->grant large at t1	0.018	0.052	0.864	-0.077	0.028	0.013	0.095	0.048	0.01
H3a, H3b	Superior at t1-->satisfaction with reputation of dept. and inst at t2	-0.179	0.061	0.014	-0.109	0.247	0.119	-0.07	0.239	0.178
	Resources at t1--->awards at t1	0.056	0.103	0.586	0.056	0.103	0.586	...	...	...
	Resources at t1--->salary at t1	-0.12	0.125	0.201	-0.12	0.125	0.201	...	...	...
	Resources at t1--->grant large at t1	-0.339	0.159	0.01	-0.339	0.159	0.01	...	...	...
H4	Resources at t1--->satisfaction with reputation of dept. and inst at t2	0.109	1.107	0.382	0.112	1.119	0.392	-0.003	0.029	0.937
	Awards at t1--->satisfaction with reputation of dept. and inst at t2	0.085	0.018	0.01	0.085	0.018	0.01	...	...	...
	Salary at t1--->satisfaction with reputation of dept. and inst at t2	0.091	0.034	0.01	0.091	0.034	0.01	...	...	...
	Grant large at t1--->satisfaction with reputation of dept. and inst at t2	-0.01	0.037	0.632	-0.01	0.037	0.632	...	...	...
	Receipt of organizational resources--->satisfaction with reputation of dept. and inst at t2	-0.023	0.021	0.219	-0.023	0.021	0.219	...	...	...
	Number of publications at t1--->satisfaction with reputation of dept. and inst at t2	0.053	0.039	0.096	0.053	0.039	0.096	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with reputation of dept. and inst at t2	-0.036	0.019	0.076	-0.036	0.019	0.076	...	...	...
	Department faculty size--->satisfaction with reputation of dept. and inst at t2	0.126	0.072	0.039	0.126	0.072	0.039	...	...	...
	Female--->satisfaction with reputation of dept. and inst at t2	-0.032	0.022	0.056	-0.032	0.022	0.056	...	...	...
	South or southeast asian--->satisfaction with reputation of dept. and inst at t2	0.038	0.057	0.142	0.038	0.057	0.142	...	...	...
	Black/African American--->satisfaction with reputation of dept. and inst at t2	0.051	0.017	0.023	0.051	0.017	0.023	...	...	...
	Hispanic--->satisfaction with reputation of dept. and inst at t2	0.013	0.022	0.566	0.013	0.022	0.566	...	...	...
	Assistant Professor--->satisfaction with reputation of dept. and inst at t2	-0.085	0.245	0.195	-0.085	0.245	0.195	...	...	...
	Associate Professor--->satisfaction with reputation of dept. and inst at t2	-0.122	0.103	0.077	-0.122	0.103	0.077	...	...	...
	Physics--->satisfaction with reputation of dept. and inst at t2	-0.052	0.127	0.166	-0.052	0.127	0.166	...	...	...
	Chemistry--->satisfaction with reputation of dept. and inst at t2	-0.08	0.262	0.225	-0.08	0.262	0.225	...	...	...
	EAS-->satisfaction with reputation of dept. and inst at t2	0.104	0.107	0.03	0.104	0.107	0.03	...	...	...
	CS--->satisfaction with reputation of dept. and inst at t2	0.014	0.097	0.549	0.014	0.097	0.549	...	...	...
	EE--->satisfaction with reputation of dept. and inst at t2	-0.002	0.098	0.986	-0.002	0.098	0.986	...	...	...

TABLE XXXI. TOTAL, DIRECT, AND INDIRECT EFFECTS (SATISFACTION WITH REPUTATION MODEL WITH WEIGHTS, WITH REWARDS AND AWARDS AT T1 AND WITH SATISFACTION WITH REPUTATION AT T1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint at t1--->superior ties at t1	-0.092	0.019	0.01	-0.092	0.019	0.01	...	...	...
	Constraint at t1--->resources at t1	0.027	0.008	0.01	...	...	...	0.027	0.008	0.01
	Constraint at t1--->awards at t1	-0.013	0.017	0.412	-0.013	0.017	0.46	0	0.004	0.841
	Constraint at t1--->salary at t1	0.015	0.016	0.339	-0.022	0.018	0.243	0.037	0.009	0.01
	Constraint at t1--->grant large at t1	-0.082	0.017	0.01	-0.08	0.018	0.01	-0.002	0.004	0.696
H1	Constraint at t1--->satisfaction with reputation of dept. and inst at t2	-0.145	0.015	0.01	-0.147	0.015	0.01	0.002	0.004	0.522
P3	Strong ties at t1-->superior ties at t1	0.35	0.029	0.01	0.35	0.029	0.01	...	...	...
P2	Strong ties at t1--->resources at t1	0.852	0.03	0.01	0.952	0.038	0.01	-0.1	0.034	0.01
	Strong ties at t1--->awards at t1	0.156	0.021	0.01	0.115	0.073	0.08	0.041	0.066	0.457
	Strong ties at t1--->salary at t1	0.155	0.023	0.01	0.392	0.105	0.01	-0.237	0.096	0.01
	Strong ties at t1--->grant large at t1	0.021	0.021	0.321	0.312	0.118	0.01	-0.29	0.112	0.01
H2a, H2b	Strong ties at t1--->satisfaction with reputation of dept. and inst at t2	-0.141	0.031	0.01	-0.39	0.159	0.01	0.249	0.14	0.01
P4	Superior ties at t1--->resources at t1	-0.287	0.095	0.01	-0.287	0.095	0.01	...	...	...
	Superior ties at t1--->awards at t1	0.001	0.045	0.841	0.013	0.033	0.605	-0.012	0.02	0.537
	Superior ties at t1--->salary at t1	-0.398	0.036	0.01	-0.428	0.025	0.01	0.03	0.03	0.246
	Superior ties at t1--->grant large at t1	0.02	0.046	0.697	-0.07	0.025	0.011	0.09	0.041	0.01
H3a, H3b	Superior at t1-->satisfaction with reputation of dept. and inst at t2	-0.038	0.042	0.407	0.06	0.049	0.176	-0.098	0.045	0.01
	Resources at t1--->awards at t1	0.043	0.078	0.537	0.043	0.078	0.537	...	...	...
	Resources at t1--->salary at t1	-0.103	0.104	0.243	-0.103	0.104	0.243	...	...	...
	Resources at t1--->grant large at t1	-0.312	0.118	0.01	-0.312	0.118	0.01	...	...	...
H4	Resources at t1--->satisfaction with reputation of dept. and inst at t2	0.247	0.124	0.01	0.248	0.137	0.01	-0.001	0.017	0.973
	Awards at t1--->satisfaction with reputation of dept. and inst at t2	0.044	0.016	0.01	0.044	0.016	0.01	...	...	...
	Salary at t1--->satisfaction with reputation of dept. and inst at t2	0.067	0.025	0.01	0.067	0.025	0.01	...	...	...
	Grant large at t1--->satisfaction with reputation of dept. and inst at t2	-0.013	0.019	0.59	-0.013	0.019	0.59	...	...	...
	Receipt of organizational resources--->satisfaction with reputation of dept. and inst at t2	-0.065	0.017	0.01	-0.065	0.017	0.01	...	...	...
	Number of publications at t1--->satisfaction with reputation of dept. and inst at t2	-0.013	0.021	0.612	-0.013	0.021	0.612	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with reputation of dept. and inst at t2	0.004	0.017	0.866	0.004	0.017	0.866	...	...	...
	Department faculty size--->satisfaction with reputation of dept. and inst at t2	-0.043	0.019	0.018	-0.043	0.019	0.018	...	...	...
	Female--->satisfaction with reputation of dept. and inst at t2	-0.022	0.017	0.207	-0.022	0.017	0.207	...	...	...
	South or southeast asian--->satisfaction with reputation of dept. and inst at t2	-0.007	0.019	0.648	-0.007	0.019	0.648	...	...	...
	Black/African American--->satisfaction with reputation of dept. and inst at t2	0.044	0.014	0.01	0.044	0.014	0.01	...	...	...
	Hispanic--->satisfaction with reputation of dept. and inst at t2	0.037	0.015	0.029	0.037	0.015	0.029	...	...	...
	Assistant Professor--->satisfaction with reputation of dept. and inst at t2	-0.148	0.042	0.01	-0.148	0.042	0.01	...	...	...
	Associate Professor--->satisfaction with reputation of dept. and inst at t2	-0.071	0.026	0.014	-0.071	0.026	0.014	...	...	...
	Physics--->satisfaction with reputation of dept. and inst at t2	-0.004	0.026	0.925	-0.004	0.026	0.925	...	...	...
	Chemistry--->satisfaction with reputation of dept. and inst at t2	-0.13	0.042	0.01	-0.13	0.042	0.01	...	...	...
	EAS-->satisfaction with reputation of dept. and inst at t2	0.016	0.024	0.584	0.016	0.024	0.584	...	...	...
	CS--->satisfaction with reputation of dept. and inst at t2	0.052	0.023	0.06	0.052	0.023	0.06	...	...	...
	EE--->satisfaction with reputation of dept. and inst at t2	-0.067	0.026	0.01	-0.067	0.026	0.01	...	...	...
	satisfaction with reputation of dept. and inst at t1--->satisfaction with reputation of dept. and inst at t2	0.701	0.014	0.01	0.701	0.014	0.01	...	...	...

6. CONCLUSIONS

6.1. Overview

The purpose of the dissertation is to understand the effects of collaborative networks on satisfaction of academic scientists. Specifically, this research explains that collaborative networks via underlying social mechanisms lead to satisfaction through the mediating influence of rewards and recognition. Said in another way, collaborative network properties lead to outcomes such as rewards and recognition, and consequently satisfaction as satisfaction results when expectations regarding rewards and recognition are fulfilled. One of the reasons scientists collaborate is because they expect collaboration to result in higher rewards and recognition. Collaboration resembles social exchange i.e. when scientists collaborate; they exchange knowledge for rewards, and recognition. However, all collaborative exchange may not result in the same levels of rewards and recognition. Depending on the network structure within which the collaborative exchange takes place, strength of the collaborative exchange relation, status of the collaborator, and resources received from the collaborators, certain collaborative exchanges may result in greater levels of rewards and recognition compared to others, and consequently higher levels of satisfaction. However, this explanation is incomplete without the role of underlying invisible social processes or mechanisms that link network structures to rewards and recognition, and consequently satisfaction. Six social mechanisms namely *social control, legitimacy, access, reciprocity, sense of personal control, validation and resource efficiency* link collaborative network properties to rewards and recognition, and consequently satisfaction. Social mechanisms are not universal i.e. they are not applicable to all collaborative network properties; while one or few may link a particular collaborative network property to outcomes, they may not link other collaborative network properties to rewards and satisfaction.

6.2. Aligning the findings to the context of academic science

This dissertation develops and tests an integrated theoretical model comprising social networks, social mechanisms, social exchange theory, and expectancy theory of motivation. This integrated theoretical model conceptualizes collaboration as social exchange and integrates it with network structural perspective, social mechanisms, and expectancy theory of motivation to explain satisfaction among academic scientists. Specifically, the integrated theoretical framework explains that collaborative exchange in certain network structures via social mechanisms lead to greater levels of rewards and recognition, and consequently satisfaction. This framework allows testing the indirect effects of collaborative networks on satisfaction through the mediating influence of rewards and recognition. Four hypotheses were formalized that focused on the indirect effects of four collaborative properties namely --collaborative network constraint, strong collaborative ties, superior status collaborators, and resources received from collaborators on satisfaction. However, collaborative networks may also affect satisfaction directly through positive evaluations of oneself and the work environment generally. Specifically, certain collaborative network structures may create positive perceptions about ones capability to achieve rewards, and favorable perceptions of the work environment more generally.

Findings indicate that the indirect effect of collaborative network constraint on satisfaction with rewards is negative and significant. Specifically, reward expectations of academic scientists remain unfulfilled as a result of collaborative exchange with a structurally powerful collaborator. The structurally powerful collaborator may be *controlling,* and may withhold rewards and professional recognition from the scientist, and hence the scientist reports a lower level of satisfaction with rewards. Previous research by Melin (2000) also found that those collaborative environments where one particular collaborator is relatively more powerful are perceived to be less rewarding than other collaborative environments where all collaborators participate equally in decision making. Scientists in constrained collaborative networks receive lower rewards, and express a lower level of satisfaction with rewards. Within the context of science this finding means that in order to earn a higher level of rewards, and consequently attain a higher level of satisfaction with rewards, scientists may need to broaden their networks by collaborating with individuals who do not necessarily know each other. In other words, the structurally constrained scientist may adopt strategies or use “agency” to overcome the constraint of his or her collaborative network. An implication of this finding within the context of academic science is that lower levels of satisfaction as a result of constrained collaborative networks may hamper scientist’s ability to form collaborative relationships. Specifically, less satisfied scientists may be less likely to trust others. Similarly, collaborators may also perceive less satisfied scientists as uncooperative. Previous literature has found that satisfied individuals are more trustworthy and cooperative (Williams and Anderson, 1991; Smith, Organ, and Near, 1983). If lower levels of satisfaction hamper scientist’s ability to form collaborative relationships, it may also hamper their research productivity, overall career success, and well-being.

Another finding in this dissertation is that scientists that have a large number of strong collaborative ties earn greater rewards and hence attain a higher level of satisfaction with rewards. This finding means that scientists are motivated to give their knowledge to strong collaborative ties. Similarly, the strong collaborative ties are motivated to accord recognition to the scientist with the expectation that the scientist would provide resources in return ranging from new knowledge to recognition and so on. This produces a reciprocity cycle. *Reciprocity* may be viewed as a mechanism through which scientists gain rewards and recognition within the scientific community. Hence, with a greater number of reciprocal collaborative ties, scientists achieve a higher level of satisfaction through fulfillment of rewards and recognition. This finding suggests that it may be worth investing time and energy in strong collaborative ties because these connections result in higher salary and large grants, and consequently higher levels of satisfaction with rewards.

Further, scientists that receive greater amount of resources from their collaborators earn greater *legitimacy,* and are able to convert those resources to rewards, and in turn report a higher level of satisfaction with rewards. This finding suggests that scientists may want to make themselves more available and visible to the collaborators so they can receive more resources in the form of introductions to potential collaborators and nominations for awards. The implication of these findings for advisors and mentors is that they may train and help scientists form strong collaborative ties to disconnected collaborators. Advisors and mentors may also train scientists in a way that scientists increase their exposure to their collaborators so as to receive introductions to other potential collaborators and nominations for awards. Next, the indirect effect of connections to superior collaborators on satisfaction with rewards was found to be negative and significant. The negative indirect effect indicates that scientists connected to a large number of superior collaborators may not able to convert those connections to rewards, and hence report a lower level of satisfaction with rewards.

Turning to satisfaction with reputation of department and institution, there is no statistical support for the hypotheses. Specifically, the indirect effects of collaborative network properties on satisfaction with reputation of department and institution through the mediating influence of rewards and recognition (salary and dollar amount of largest grant) is not statistically significant as salary and dollar amount of largest grant are unrelated to satisfaction with reputation of department and institution. Perhaps, other measures of rewards and recognition may work for satisfaction with reputation of department and institution.

The previous paragraphs discussed the meaning of findings within the context of academic science. In the next section, the contribution of this dissertation is discussed. There are four areas of contribution offered by this dissertation. These four areas are social networks, social mechanisms, work satisfaction, and research collaboration.

6.3. Social networks

The first contribution offered by of this dissertation is in the area of social networks. First, this dissertation presents a holistic picture of the effects of networks on satisfaction by including a broad range of network properties. Several previous studies look at one or few network properties and their relationship with satisfaction. Second, this dissertation also recognizes that certain network properties may have negative effects on outcomes. Third, this research explains two routes through which networks lead to satisfaction. The first is the direct route through which network structures creates either favorable or negative perceptions, which then affects satisfaction; second is the indirect route which explains that networks indirectly affect satisfaction through objective outcomes such as rewards and recognition. These theoretical contributions are discussed below in detail. Additionally, empirical contributions offered by this dissertation to the field of social networks are also discussed.

6.3.1. Theoretical contributions

Four network properties—network constraint, strength of ties, status of the alter, and resources received from alters are included in this research. The above four network properties focus on different aspects of networks. Network constraint focuses on the pattern of connection between alters. Strength of ties focus on the nature of ties, Status of alters refers to the superiority of alters in terms of expertise, seniority, and skills. Resource received from alters focuses on the desirable resources that the ego receives from alters which helps the ego achieve career goals. An integration of these four network properties was possible because they are distinct and focus on different aspects. Integration of these four network properties presents a holistic picture of networks, and enhances our understanding of the effects of networks on satisfaction.

Next, this dissertation recognizes that previous studies often focus on the positive role of networks and neglect the fact that networks sometimes have negative effects on the ego level outcomes. This research looks at the dark side of social networks by recognizing that network constraint may lead to lower levels of satisfaction. Specifically, in a constrained network structure, the ego is dependent on a structurally powerful alter, and have lower access to resources, and may not be able to attain rewards, and consequently report a lower level of satisfaction. The structurally powerful alter may also withhold rewards and recognition from the ego. As a result, the ego may perceive to be less legitimate, less valued, and hence may not be able to fulfill his or her reward expectations.

Further, this dissertation acknowledges that network can lead to satisfaction directly as well as indirectly. Although direct effects of networks on satisfaction have not been formally hypothesized, it is recognized that networks structures creates perceptions about oneself and about the work environment. For example, egos' located in constrained network structures form negative perceptions about their capabilities of attaining rewards and recognition because they perceive being socially less valued, less legitimate, and controlled by a structurally powerful collaborators, and as a result their satisfaction levels are lower. Further, as formally hypothesized, networks can lead to satisfaction indirectly through the mediating influence of rewards and recognition.

6.3.2. Empirical contribution

This dissertation demonstrates that intervening variables such as rewards and recognition do mediate the extent to which collaborative networks determine satisfaction. The indirect effects of four networks properties on satisfaction through the intervening variables such as reward, and others is well explained in this dissertation. Empirical findings showed that as expected, the indirect of network constraint on satisfaction is negative and significant; suggesting that collaborative exchange with a relatively powerful collaborator may not lead to lower levels of rewards and recognition, and consequently lower levels of satisfaction with rewards. Another empirical finding showed that the indirect effect of strong ties on satisfaction is positive and significant; suggesting that strong reciprocal ties are able to fulfill reward expectations of scientists, and hence they report a higher level of satisfaction.

6.4. Social mechanisms

The second theoretical contribution offered by this dissertation is the recognition of underlying social processes or mechanisms that link network structures and satisfaction. The six social mechanisms discussed in this dissertation research are 1) social control, 2) legitimacy, 3) access, 4) reciprocity, 5) sense of personal control, and 6) validation and resource efficiency. These social mechanisms link the four network properties to reward outcomes and consequently satisfaction. However, social mechanisms are not universal laws that can be applied to each network property. For example, while certain social mechanism may link network constraint to rewards and consequently to satisfaction, they may not link other network properties such as strong ties to satisfaction. In other words, social mechanisms are structure specific. In taking a social mechanisms approach to understanding the relationship between networks, rewards, and satisfaction, this dissertation makes an important theoretical contribution to the emerging analytical social science literature. However, it is important to recognize that since social mechanisms are invisible and cannot be empirically tested; there may be limitations to the extent they contribute to linking network structures and satisfaction.

6.5. Satisfaction

The third contribution offered by this dissertation is within the area of work satisfaction. The concept of satisfaction in this dissertation is defined in terms of two core ideas: rewards and expectations. Specifically, satisfaction results when reward expectations are met. This dissertation discusses that within the context of academic science, one of the primary motivations of faculty is attainment of rewards and recognition. Faculty form and participate in collaborative networks which provides them rewards and recognition, and consequently satisfaction. An integrated theoretical framework allows the integration of the three concepts—collaborative networks, rewards, and fulfillment of reward expectations to explain satisfaction. The theoretical and empirical contribution is discussed below.

6.5.1. Theoretical contribution

Satisfaction in this dissertation is explained through an integration of social exchange theory, expectancy theory of motivation and a social network theoretical perspective. Specifically, exchange within certain network structures and exchange with certain ties provide access to valuable resources, which helps the individual attain rewards and professional recognition. Satisfaction results when reward expectations are met. For example, collaborative exchange in constrained network structures may lead to lower rewards and recognition, and consequently lower levels of satisfaction as the relatively powerful collaborator may withhold rewards and recognition from the scientists. In integrating the above three theoretical frameworks to explain the effects of collaborative networks on satisfaction of academic scientists, this dissertation makes an important theoretical contribution to the satisfaction literature.

6.5.2. Empirical contribution

One of the most important empirical contributions of this research is that it attempts to test a theoretical framework that integrates social network theoretical perspective, social exchange theory, and expectancy theory of motivation to explain the effects of collaborative networks on satisfaction. Another empirical contribution offered by this dissertation is that it tests the effects of collaborative networks on two kinds of satisfaction. In other words, this dissertation takes a broader view of satisfaction by including two kinds of satisfaction—one that is more concerned with perceptions of one's own professional success, and the other that is concerned with perception of one's department and institution. Findings from path analysis suggest that collaborative network properties contribute differently to the two kinds of satisfaction. For example, the indirect effect of collaborative network constraint on satisfaction with rewards is negative and significant, whereas on satisfaction with reputation of department and institution is positive and significant.

6.6. Research collaboration

The fourth contribution offered by this dissertation is that it recognizes the similarity between the process of social exchange and research collaboration. Although previous research has also discussed that when faculty members collaborate on research, they provide knowledge, skills, and expertise to their collaborators and in turn receive recognition and credibility (Rijnsoever et al, 2008), but less attention has been given to integrate social exchange theory with network structural perspective to explain the effects of collaboration on satisfaction among academic faculty in the science fields. An integration of social exchange theory and network structural perspective argues that as collaboration resembles social exchange, a large number of strong collaborative ties may lead to greater research visibility and recognition for the scientist. In other words, the existence of a large number of strong collaborative ties increases the possibility that the scientist might receive a higher level of recognition and rewards as strong ties are reciprocal. Further, this dissertation discusses that faculty members within science are satisfied to the extent that their expectations for recognition and rewards are met or fulfilled. Specifically, strong collaborative ties may lead to higher levels of rewards and recognition, and consequently higher levels of satisfaction. The specific theoretical and empirical contribution offered by this dissertation within the area of research collaboration is discussed below.

6.6.1. Theoretical contribution

This dissertation recognizes that social exchange occurs within structures of mutual dependence and that both social exchange theorists and network theorists both view social structure as a configuration of exchange relations involving the exchange of valued items (material, informational, symbolic) (Cook and Whimeyer, 1992; Molm, 1991, 2000; Lawler and Thye, 2006). Hence, this study finds it appropriate to analyze exchange relations as social network relations and apply network concepts to understand the effects of exchange relations on outcomes such as rewards and recognition. Certain exchange relations may provide more valued outcomes or rewards to one another than others. For example, strongly ties exchange relations may provide more rewards and recognition as they are more likely to be reciprocal. Further, this dissertation applies expectancy theory of motivation to explain that when expectation of rewards and recognition are met, an individual may report a higher level of satisfaction. Specifically, social exchange theory, network structural perspective, and expectancy theory of motivation is integrated to explain the effects of collaborative networks on satisfaction of academic scientists.

6.6.2. Empirical contribution

This dissertation tests the theoretical framework integrating social exchange theory, network structural perspective, and expectancy theory of motivation to understand the indirect effects of collaborative networks on satisfaction through the mediating influence of rewards and recognition. By testing this integrated framework, this dissertation makes an important empirical contribution to the literature on research collaboration of academic scientists. Four hypotheses were formalized that focused on the indirect effects of four collaborative properties namely -- collaborative network constraint, strong collaborative ties, superior collaborators, and resources received from collaborators on satisfaction. As expected, support was found for many of the hypotheses.

6.7. Importance of this dissertation to public administration

This dissertation promises to make broader impacts in mainstream public administration. It has contributed to our understanding of the effects of collaborative network on work satisfaction. Both work satisfaction and collaboration are important issues in the public sector. For example, work satisfaction in the public sector impacts physical well-being, psychological health, absenteeism, turnover among public managers. Also, collaborative interaction within the public sector is likely to increase in frequency as problems become more complex, funding becomes more limited, and new information and communication technologies enable virtual interaction. Knowledge developed in this study on the effects of collaborative interactions on satisfaction may inform the public managers that outcome such as satisfaction is likely related to the network structure than individual capacities. Theory and empirical findings from this dissertation may inform public managers such that they may be able to influence work satisfaction through the active construction of teams.

6.8. Limitations of this research

It is important to recognize the limitations of this research. First, the sample used in this dissertation includes academic faculty from six fields of science and engineering in Research I universities. Hence, the findings from this dissertation can be generalized to population in Research I universities within science and engineering fields. Testing this sample in social science fields such as public administration and others may lead to different findings as the work context in science fields is different compared to social sciences. For example, science fields are marked by high degrees of quantification, use of labs and instruments, interdependence in research as compared to social science. Scientists collaborate in order to use labs, get access to complex methodologies and instruments and so on.

Second, this dissertation may be limited by the way rewards and recognition is captured. Specifically, rewards and recognition were measured by only two items namely salary and dollar amount of largest grant. Including other measures of recognition such as membership in honorific societies, service on an editorial board of a journal, or perceptual measures of recognition such as scientist's own evaluation of their recognition among their collaborators and in the field, scientist's perception of whether they have received proper credit for their contribution and so on may have added richness to the findings. Inability to collect data on these additional measures of recognition may be a limitation of this study. Additionally, controlling for factors such as the amount of time spent on a research area/topic, or continuity in research interest predict recognition won by scientists may have led to interesting findings. With regards to networks, inclusion of cognitive network factors such as perceived understanding of collaborator's expertise, and relational constructs such as homophily of collaborative ties may have added greater insights to the findings.

Third, this dissertation may be limited by the validity of the measures. For example, senior ties may not always reflect superiority of collaborators. When asked whether the collaborator is a senior, scientists may interpret differently. Some may just guess about whether the collaborator is a senior, or sometimes out of humility, the scientist may name the collaborator as a senior. Including other measures of superiority such as scientist's perception of the collaborator in terms of knowledge, skills, and expertise may better capture superiority of collaborators, and hence improve the validity of this measure.

Fourth, although the availability of networks, rewards, and satisfaction data at two points in time enhanced our ability to establish causality in the relationship between networks at time t1 and satisfaction at time t2, future studies should include data at three points in time to study the relationship between networks at time t1, rewards at time t2, and satisfaction at t3. However, it is important to acknowledge that it is hard to collect comprehensive longitudinal data for three points in time especially for ego centric network analysis.

6.9. Future research directions

This dissertation opens up interesting future research directions. This study is focused to understand the effects of collaborative network on satisfaction. Collaboration has been conceptualized as social exchange. Collaborative ties convey knowledge and recognition. It would be exciting to see the effects of advice networks on satisfaction through the mediating influence of rewards and recognition, and compare the findings with collaborative networks. Advice may be conceptualized as social support. Advice ties convey informational support. A comparison of collaborative and advice networks in terms of how they contribute to satisfaction of academic scientists may be an interesting future research agenda.

Second, the effects of collaborative networks on satisfaction through the mediating influence of rewards and recognition could be studied across faculty ranks. Faculty members in university science departments at different stages of their career in terms of rank attribute their rewards and satisfaction to a different set of factors (Olsen et al, 1995). As a result, one may expect that collaborative network structures affect assistant professor's satisfaction as well as their reward outcomes differently compared to associate and full professors. Exploring how collaborative network factors contribute to the satisfaction of academic scientists across rank may be an interesting future research agenda.

Third, building on the research agenda of this dissertation that contributes to the understanding of the effects of collaborative networks on satisfaction, other relational and cognitive network characteristics could be integrated. For example, relational characteristics such as homophilous ties and cognitive characteristics such as ego's understanding of alter's expertise could be included in the model.

Finally, as both work satisfaction and collaborative interactions are important in the public sector, the model developed in this dissertation research may be tested for public managers.

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Appendix

Table 1. Total, direct, and indirect effects (predicting satisfaction with rewards at t2, with rewards at t2, with satisfaction with rewards at t1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**
P1	Constraint--->superior ties	-0.099	0.019	0.01	-0.099	0.019	0.01	...	...	...
	Constraint--->resources	0.000	0.003	0.921	...	...	...	0.000	0.003	0.921
	Constraint--->salary at t2	0.015	0.015	0.319	-0.03	0.017	0.116	0.045	0.009	0.01
	Constraint--->grant large at t2	0.031	0.018	0.073	0.019	0.018	0.196	0.012	0.003	0.01
H1	Constraint--->satisfaction with rewards at t2	-0.046	0.017	0.012	-0.031	0.017	0.061	-0.015	0.005	0.01
P3	Strong ties-->superior ties	0.489	0.022	0.01	0.489	0.022	0.01	...	...	...
P2	Strong ties--->resources	0.817	0.018	0.01	0.816	0.022	0.01	0.001	0.013	0.921
	Strong ties--->salary at t2	0.071	0.024	0.01	0.152	0.075	0.037	-0.081	0.063	0.201
	Strong ties--->grant large at t2	0.053	0.018	0.015	0.156	0.054	0.01	-0.103	0.05	0.038
H2a, H2b	Strong ties--->satisfaction with rewards at t2	-0.108	0.023	0.01	-0.461	0.079	0.01	0.353	0.068	0.01
P4	Superior ties--->resources	0.002	0.027	0.921	0.002	0.027	0.921	...	...	...
	Superior ties--->salary at t2	-0.455	0.022	0.01	-0.456	0.022	0.01	0.000	0.005	0.931
	Superior ties--->grant large at t2	-0.125	0.024	0.01	-0.125	0.024	0.01	0.000	0.002	0.911
H3a,H3b	Superior ties--->satisfaction with rewards at t2	0.157	0.041	0.01	0.118	0.041	0.01	0.038	0.017	0.022
	Resources--->salary at t2	0.173	0.073	0.017	0.173	0.073	0.017	...	...	...
	Resources--->grant large at t2	-0.051	0.061	0.339	-0.051	0.061	0.339	...	...	...
H4	Resources--->satisfaction with rewards at t2	0.364	0.068	0.01	0.371	0.072	0.01	-0.008	0.01	0.404
	Salary at t2--->satisfaction with rewards at t2	-0.064	0.028	0.042	-0.064	0.028	0.042	...	...	...
	Grant large at t2--->satisfaction with rewards at t2	-0.069	0.017	0.01	-0.069	0.017	0.01	...	...	...
	Receipt of organizational resources--->satisfaction with rewards at t2	-0.006	0.017	0.656	-0.006	0.017	0.656	...	...	...
	Number of publications at t1--->satisfaction with rewards at t2	0.047	0.022	0.06	0.047	0.022	0.06	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with rewards at t2	0.1	0.023	0.01	0.1	0.023	0.01	...	...	...
	Dept faculty size--->satisfaction with rewards at t2	-0.139	0.025	0.01	-0.139	0.025	0.01	...	...	...
	Female--->satisfaction with rewards at t2	-0.042	0.016	0.018	-0.042	0.016	0.018	...	...	...
	South or southeast asian--->satisfaction with rewards at t2	0.047	0.018	0.01	0.047	0.018	0.01	...	...	...
	Black/African American--->satisfaction with rewards at t2	0.036	0.015	0.024	0.036	0.015	0.024	...	...	...
	Hispanic--->satisfaction with rewards at t2	0.000	0.015	0.979	0.000	0.015	0.979	...	...	...
	Assistant Professor--->satisfaction with rewards at t2	-0.254	0.036	0.01	-0.254	0.036	0.01	...	...	...
	Associate Professor--->satisfaction with rewards at t2	-0.106	0.022	0.01	-0.106	0.022	0.01	...	...	...
	Physics--->satisfaction with rewards at t2	-0.031	0.022	0.156	-0.031	0.022	0.156	...	...	...
	Chemistry--->satisfaction with rewards at t2	-0.061	0.031	0.03	-0.061	0.031	0.03	...	...	...
	EAS-->satisfaction with rewards at t2	-0.069	0.023	0.01	-0.069	0.023	0.01	...	...	...
	CS--->satisfaction with rewards at t2	0.013	0.022	0.593	0.013	0.022	0.593	...	...	...
	EE--->satisfaction with rewards at t2	-0.049	0.022	0.032	-0.049	0.022	0.032	...	...	...
	Satisfaction with rewards at t1--->satisfaction with rewards at t2	0.733	0.019	0.01	0.733	0.019	0.01	...	...	...

Table 2. Total, direct, and indirect effects (predicting satisfaction with reputation at t2, with rewards at t2, with satisfaction with reputation at t1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**
P1	Constraint--->superior ties	-0.119	0.018	0.01	-0.119	0.018	0.01	...	...	...
	Constraint--->resources	-0.019	0.005	0.01	...	...	...	-0.019	0.005	0.01
	Constraint--->salary at t2	0.021	0.016	0.141	-0.031	0.016	0.092	0.052	0.008	0.01
	Constraint--->grant large at t2	0.031	0.018	0.071	0.022	0.019	0.229	0.01	0.003	0.01
H1	Constraint--->satisfaction with reputation of dept. and inst at t2	-0.144	0.02	0.01	-0.147	0.02	0.01	0.003	0.004	0.369
P3	Strong ties-->superior ties	0.411	0.024	0.01	0.411	0.024	0.01	...	...	...
P2	Strong ties--->resources	0.714	0.02	0.01	0.648	0.027	0.01	0.066	0.013	0.01
	Strong ties--->salary at t2	0.176	0.016	0.01	0.315	0.037	0.01	-0.139	0.034	0.01
	Strong ties--->grant large at t2	0.065	0.021	0.01	0.13	0.034	0.01	-0.065	0.026	0.018
H2a, H2b	Strong ties--->satisfaction with reputation of dept. and inst at t2	-0.097	0.024	0.01	-0.097	0.034	0.01	0.000	0.024	0.94
P4	Superior ties--->resources	0.159	0.03	0.01	0.159	0.03	0.01	...	...	...
	Superior ties--->salary at t2	-0.436	0.024	0.01	-0.446	0.025	0.01	0.01	0.008	0.182
	Superior ties--->grant large at t2	-0.083	0.026	0.01	-0.075	0.027	0.012	-0.008	0.006	0.162
H3a,H3b	Superior ties--->satisfaction with reputation of dept. and inst at t2	-0.024	0.027	0.39	-0.046	0.03	0.156	0.023	0.012	0.037
	Resources--->salary at t2	0.062	0.045	0.182	0.062	0.045	0.182	...	...	...
	Resources--->grant large at t2	-0.048	0.036	0.163	-0.048	0.036	0.163	...	...	...
H4	Resources--->satisfaction with reputation of dept. and inst at t2	0.036	0.032	0.254	0.037	0.032	0.242	-0.001	0.003	0.801
	Salary at t2--->satisfaction with reputation of dept. and inst at t2	-0.033	0.024	0.132	-0.033	0.024	0.132	...	...	...
	Grant large at t2--->satisfaction with reputation of dept. and inst at t2	-0.027	0.015	0.079	-0.027	0.015	0.079	...	...	...
	Receipt of organizational resources--->satisfaction with reputation of dept. and inst at t2	-0.019	0.014	0.159	-0.019	0.014	0.159	...	...	...
	Number of publications at t1--->satisfaction with reputation of dept. and inst at t2	0.042	0.018	0.028	0.042	0.018	0.028	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with reputation of dept. and inst at t2	-0.053	0.015	0.01	-0.053	0.015	0.01	...	...	...
	Dept faculty size--->satisfaction with reputation of dept. and inst at t2	0.000	0.017	0.904	0.000	0.017	0.904	...	...	...
	Female--->satisfaction with reputation of dept. and inst at t2	-0.036	0.015	0.034	-0.036	0.015	0.034	...	...	...
	South or southeast asian--->satisfaction with reputation of dept. and inst at t2	-0.059	0.015	0.01	-0.059	0.015	0.01	...	...	...
	Black/African American--->satisfaction with reputation of dept. and inst at t2	0.049	0.016	0.01	0.049	0.016	0.01	...	...	...
	Hispanic--->satisfaction with reputation of dept. and inst at t2	0.039	0.015	0.035	0.039	0.015	0.035	...	...	...
	Assistant Professor--->satisfaction with reputation of dept. and inst at t2	-0.101	0.023	0.01	-0.101	0.023	0.01	...	...	...
	Associate Professor--->satisfaction with reputation of dept. and inst at t2	-0.039	0.018	0.022	-0.039	0.018	0.022	...	...	...
	Physics--->satisfaction with reputation of dept. and inst at t2	0.017	0.017	0.32	0.017	0.017	0.32	...	...	...
	Chemistry--->satisfaction with reputation of dept. and inst at t2	-0.036	0.021	0.047	-0.036	0.021	0.047	...	...	...
	EAS-->satisfaction with reputation of dept. and inst at t2	0.061	0.019	0.011	0.061	0.019	0.011	...	...	...
	CS--->satisfaction with reputation of dept. and inst at t2	0.076	0.02	0.01	0.076	0.02	0.01	...	...	...
	EE--->satisfaction with reputation of dept. and inst at t2	-0.003	0.018	0.966	-0.003	0.018	0.966	...	...	...
	Satisfaction with reputation of dept. and inst at t1--->satisfaction with reputation of dept. and inst at t2	0.706	0.014	0.01	0.706	0.014	0.01	...	...	...

Table 3. Total, direct, and indirect effects without weights (predicting satisfaction with rewards at t2, with rewards at t2, with satisfaction with rewards at t1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**
P1	Constraint--->superior ties	-0.175	0.049	0.01	-0.175	0.049	0.01	...	...	...
	Constraint--->resources	-0.011	0.012	0.227	...	...	...	-0.011	0.012	0.227
	Constraint--->salary at t2	0.059	0.042	0.177	0.01	0.048	0.848	0.048	0.018	0.01
	Constraint--->grant large at t2	0.034	0.046	0.521	0.014	0.048	0.772	0.02	0.013	0.041
H1	Constraint--->satisfaction with rewards at t2	-0.016	0.042	0.598	0.009	0.043	0.887	-0.025	0.016	0.083
P3	Strong ties-->superior ties	0.311	0.058	0.01	0.311	0.058	0.01	...	...	
P2	Strong ties--->resources	0.751	0.044	0.01	0.751	0.048	0.01	0.02	0.018	0.224
	Strong ties--->salary at t2	0.116	0.051	0.028	0.116	0.112	0.233	0.003	0.095	0.819
	Strong ties--->grant large at t2	0.092	0.052	0.255	0.092	0.124	0.495	-0.03	0.106	0.878
H2a, H2b	Strong ties--->satisfaction with rewards at t2	-0.282	0.054	0.025	-0.282	0.116	0.01	0.149	0.091	0.071
P4	Superior ties--->resources	0.064	0.06	0.225	0.064	0.06	0.225	...	...	...
	Superior ties--->salary at t2	-0.277	0.055	0.01	-0.284	0.054	0.01	0.008	0.012	0.497
	Superior ties--->grant large at t2	-0.114	0.057	0.042	-0.114	0.058	0.04	0.000	0.012	0.904
H3a,H3b	Superior ties--->satisfaction with rewards at t2	0.138	0.078	0.072	0.113	0.081	0.186	0.025	0.021	0.184
	Resources--->salary at t2	0.118	0.117	0.355	0.118	0.117	0.355	...	...	...
	Resources--->grant large at t2	0.007	0.134	0.867	0.007	0.134	0.867	...	...	...
H4	Resources--->satisfaction with rewards at t2	0.154	0.11	0.165	0.158	0.112	0.172	-0.004	0.014	0.725
	Salary at t2--->satisfaction with rewards at t2	-0.029	0.051	0.632	-0.029	0.051	0.632	...	...	...
	Grant large at t2--->satisfaction with rewards at t2	-0.065	0.038	0.101	-0.065	0.038	0.101	...	...	...
	Receipt of organizational resources--->satisfaction with rewards at t2	0.028	0.05	0.535	0.028	0.05	0.535	...	...	...
	Number of publications at t1--->satisfaction with rewards at t2	0.045	0.042	0.291	0.045	0.042	0.291	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with rewards a	0.012	0.039	0.76	0.012	0.039	0.76	...	...	...
	Dept faculty size--->satisfaction with rewards at t2	-0.083	0.045	0.048	-0.083	0.045	0.048	...	...	...
	Female--->satisfaction with rewards at t2	-0.047	0.042	0.228	-0.047	0.042	0.228	...	...	...
	South or southeast asian--->satisfaction with rewards at t2	-0.014	0.041	0.651	-0.014	0.041	0.651	...	...	...
	Black/African American--->satisfaction with rewards at t2	0.079	0.038	0.011	0.079	0.038	0.011	...	...	...
	Hispanic--->satisfaction with rewards at t2	0.021	0.039	0.584	0.021	0.039	0.584	...	...	...
	Assistant Professor--->satisfaction with rewards at t2	-0.259	0.082	0.01	-0.259	0.082	0.01	...	...	...
	Associate Professor--->satisfaction with rewards at t2	-0.136	0.057	0.02	-0.136	0.057	0.02	...	...	...
	Physics--->satisfaction with rewards at t2	0.005	0.047	0.899	0.005	0.047	0.899	...	...	...
	Chemistry--->satisfaction with rewards at t2	0.008	0.049	0.856	0.008	0.049	0.856	...	...	...
	EAS-->satisfaction with rewards at t2	0.024	0.047	0.608	0.024	0.047	0.608	...	...	...
	CS--->satisfaction with rewards at t2	0.048	0.049	0.333	0.048	0.049	0.333	...	...	...
	EE--->satisfaction with rewards at t2	-0.002	0.044	0.976	-0.002	0.044	0.976	...	...	...
	Satisfaction with rewards at t1--->satisfaction with rewards at t2	0.706	0.042	0.01	0.706	0.042	0.01	...	...	...

Table 4. Total, direct, and indirect effects without weights (predicting satisfaction with reputation at t2, with rewards at t2, with satisfaction with reputation at t1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**	**Std. Est.**	**S.E**	**Sig.**
P1	Constraint--->superior ties	-0.163	0.047	0.01	-0.163	0.047	0.01	...	...	...
	Constraint--->resources	-0.014	0.012	0.235	...	...	...	-0.014	0.012	0.235
	Constraint--->salary at t2	0.065	0.045	0.154	0.014	0.046	0.788	0.05	0.017	0.01
	Constraint--->grant large at t2	0.042	0.048	0.386	0.029	0.049	0.535	0.013	0.011	0.173
H1	Constraint--->satisfaction with reputation of dept. and inst at t2	-0.051	0.04	0.201	-0.059	0.04	0.156	0.007	0.012	0.465
P3	Strong ties-->superior ties	0.3	0.064	0.01	0.3	0.064	0.01	...	...	
P2	Strong ties--->resources	0.755	0.045	0.01	0.729	0.052	0.01	0.026	0.021	0.237
	Strong ties--->salary at t2	0.178	0.053	0.01	0.264	0.108	0.022	-0.086	0.092	0.375
	Strong ties--->grant large at t2	0.047	0.053	0.458	0.09	0.105	0.359	-0.043	0.082	0.545
H2a, H2b	Strong ties--->satisfaction with reputation of dept. and inst at t2	-0.068	0.057	0.265	-0.108	0.108	0.309	0.04	0.076	0.601
P4	Superior ties--->resources	0.087	0.068	0.237	0.087	0.068	0.237	...	...	...
	Superior ties--->salary at t2	-0.307	0.057	0.01	-0.308	0.06	0.01	0.001	0.014	0.933
	Superior ties--->grant large at t2	-0.079	0.059	0.172	-0.076	0.061	0.201	-0.002	0.012	0.839
H3a, H3b	Superior ties--->satisfaction with reputation of dept. and inst at t2	-0.046	0.073	0.377	-0.048	0.078	0.392	0.002	0.019	0.829
	Resources--->salary at t2	0.008	0.118	0.902	0.008	0.118	0.902	...	...	...
	Resources--->grant large at t2	-0.027	0.109	0.723	-0.027	0.109	0.723	...	...	...
H4	Resources--->satisfaction with reputation of dept. and inst at t2	0.071	0.095	0.433	0.07	0.097	0.427	0.001	0.008	0.997
	Salary at t2--->satisfaction with reputation of dept. and inst at t2	0.019	0.047	0.729	0.019	0.047	0.729	...	...	...
	Grant large at t2--->satisfaction with reputation of dept. and inst at t2	-0.025	0.04	0.545	-0.025	0.04	0.545	...	...	...
	Receipt of organizational resources--->satisfaction with reputation of dept. and inst at t2	0.012	0.036	0.725	0.012	0.036	0.725	...	...	...
	Number of publications at t1--->satisfaction with reputation of dept. and inst at t2	0.019	0.044	0.6	0.019	0.044	0.6	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with reputation of dept. and inst at t2	-0.053	0.039	0.189	-0.053	0.039	0.189	...	...	...
	Dept faculty size--->satisfaction with reputation of dept. and inst at t2	-0.04	0.045	0.392	-0.04	0.045	0.392	...	...	...
	Female--->satisfaction with reputation of dept. and inst at t2	-0.046	0.038	0.282	-0.046	0.038	0.282	...	...	...
	South or southeast asian--->satisfaction with reputation of dept. and inst at t2	-0.063	0.035	0.055	-0.063	0.035	0.055	...	...	...
	Black/African American--->satisfaction with reputation of dept. and inst at t2	0.066	0.036	0.044	0.066	0.036	0.044	...	...	...
	Hispanic--->satisfaction with reputation of dept. and inst at t2	0.02	0.039	0.721	0.02	0.039	0.721	...	...	...
	Assistant Professor--->satisfaction with reputation of dept. and inst at t2	-0.088	0.064	0.191	-0.088	0.064	0.191	...	...	...
	Associate Professor--->satisfaction with reputation of dept. and inst at t2	-0.025	0.044	0.641	-0.025	0.044	0.641	...	...	...
	Physics--->satisfaction with reputation of dept. and inst at t2	0.018	0.047	0.697	0.018	0.047	0.697	...	...	...
	Chemistry--->satisfaction with reputation of dept. and inst at t2	-0.007	0.048	0.834	-0.007	0.048	0.834	...	...	...
	EAS-->satisfaction with reputation of dept. and inst at t2	0.054	0.05	0.243	0.054	0.05	0.243	...	...	...
	CS--->satisfaction with reputation of dept. and inst at t2	0.052	0.046	0.254	0.052	0.046	0.254	...	...	...
	EE--->satisfaction with reputation of dept. and inst at t2	0.005	0.045	0.778	0.005	0.045	0.778	...	...	...
	Satisfaction with reputation of dept. and inst at t2--->satisfaction with reputation of dept. and inst at t2	0.688	0.033	0.01	0.688	0.033	0.01	...	...	...

Table 5. Total, direct, and indirect effects without weights (predicting satisfaction with rewards at t2, with rewards at t1, with satisfaction with rewards at t1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint at t1--->superior ties at t1	-0.141	0.05	0.01	-0.141	0.05	0.01	...	...	...
	Constraint at t1--->resources at t1	0.004	0.012	0.873	...	...	...	0.004	0.012	0.873
	Constraint at t1--->awards at t1	-0.035	0.046	0.419	-0.032	0.047	0.492	-0.003	0.009	0.716
	Constraint at t1--->salary at t1	-0.004	0.044	0.885	-0.069	0.047	0.136	0.065	0.022	0.01
	Constraint at t1--->grant large at t1	-0.016	0.048	0.674	-0.033	0.049	0.483	0.017	0.01	0.029
H1	Constraint at t1--->satisfaction with rewards at t2	0.001	0.045	0.967	0.016	0.047	0.848	-0.015	0.017	0.327
P3	Strong ties at t1-->superior ties at t1	0.41	0.061	0.01	0.41	0.061	0.01	...	...	...
P2	Strong ties at t1--->resources at t1	0.785	0.052	0.01	0.795	0.073	0.01	-0.01	0.034	0.873
	Strong ties at t1--->awards at t1	0.097	0.055	0.083	0.002	0.138	0.998	0.095	0.123	0.279
	Strong ties at t1--->salary at t1	0.109	0.05	0.047	0.214	0.182	0.163	-0.105	0.16	0.422
	Strong ties at t1--->grant large at t1	0.095	0.056	0.086	0.267	0.192	0.043	-0.172	0.175	0.089
H2a, H2b	Strong ties at t1--->satisfaction with rewards at t2	-0.125	0.056	0.029	-0.295	0.215	0.028	0.17	0.202	0.068
P4	Superior ties at t1--->resources at t1	-0.025	0.079	0.873	-0.025	0.079	0.873	...	...	...
	Superior ties at t1--->awards at t1	0.018	0.056	0.715	0.021	0.057	0.644	-0.003	0.018	0.917
	Superior ties at t1--->salary at t1	-0.461	0.065	0.01	-0.459	0.066	0.01	-0.003	0.014	0.807
	Superior ties at t1--->grant large at t1	-0.119	0.059	0.029	-0.123	0.066	0.027	0.004	0.022	0.849
H3a, H3b	Superior at t1-->satisfaction with rewards at t2	0.122	0.095	0.217	0.119	0.103	0.264	0.003	0.045	0.955
	Resources at t1--->awards at t1	0.11	0.138	0.268	0.11	0.138	0.268	...	...	...
	Resources at t1--->salary at t1	0.105	0.164	0.517	0.105	0.164	0.517	...	...	...
	Resources at t1--->grant large at t1	-0.155	0.183	0.213	-0.155	0.183	0.213	...	...	...
H4	Resources at t1--->satisfaction with rewards at t2	0.16	0.167	0.195	0.163	0.195	0.195	-0.003	0.038	0.776
	Salary at t1--->satisfaction with rewards at t2	-0.012	0.057	0.944	-0.012	0.057	0.944	...	...	...
	Grant large at t1--->satisfaction with rewards at t2	-0.016	0.045	0.668	-0.016	0.045	0.668	...	...	...
	Awards at t1--->satisfaction with rewards at t2	-0.037	0.038	0.315	-0.037	0.038	0.315	...	...	...
	Receipt of organizational resources--->satisfaction with rewards at t2	-0.045	0.041	0.287	-0.045	0.041	0.287	...	...	...
	Number of publications at t1--->satisfaction with rewards at t2	0.038	0.048	0.34	0.038	0.048	0.34	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with rewards at t2	0.017	0.042	0.584	0.017	0.042	0.584	...	...	...
	Department faculty size--->satisfaction with rewards at t2	-0.074	0.047	0.1	-0.074	0.041	0.1	...	...	...
	Female--->satisfaction with rewards at t2	-0.065	0.037	0.091	-0.065	0.037	0.091	...	...	...
	South or southeast asian--->satisfaction with rewards at t2	-0.031	0.039	0.368	-0.031	0.039	0.368	...	...	...
	Black/African American--->satisfaction with rewards at t2	0.086	0.033	0.01	0.086	0.033	0.01	...	...	...
	Hispanic--->satisfaction with rewards at t2	0.024	0.041	0.53	0.024	0.041	0.53	...	...	...
	Assistant Professor--->satisfaction with rewards at t2	-0.214	0.075	0.01	-0.214	0.075	0.01	...	...	...
	Associate Professor--->satisfaction with rewards at t2	-0.13	0.053	0.017	-0.13	0.053	0.017	...	...	...
	Physics--->satisfaction with rewards at t2	0	0.051	0.939	0	0.051	0.939	...	...	...
	Chemistry--->satisfaction with rewards at t2	-0.01	0.05	0.842	-0.01	0.05	0.842	...	...	...
	EAS-->satisfaction with rewards at t2	0.051	0.051	0.334	0.051	0.051	0.334	...	...	...
	CS--->satisfaction with rewards at t2	0.054	0.051	0.26	0.054	0.051	0.26	...	...	...
	EE--->satisfaction with rewards at t2	0.004	0.052	0.979	0.004	0.052	0.979	...	...	...
	Satisfaction with rewards at t1--->satisfaction with rewards at t2	0.693	0.047	0.01	0.693	0.047	0.01	...	...	...

Table 6. Total, direct, and indirect effects without weights (predicting satisfaction with reputation at t2, with rewards at t1, with satisfaction with reputation at t1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint at t1--->superior ties at t1	-0.196	0.047	0.01	-0.196	0.047	0.01	...	...	...
	Constraint at t1--->resources at t1	-0.003	0.017	0.756	...	...	...	-0.003	0.017	0.756
	Constraint at t1--->awards at t1	-0.06	0.047	0.237	-0.055	0.047	0.279	-0.006	0.012	0.648
	Constraint at t1--->salary at t1	-0.031	0.038	0.487	-0.12	0.043	0.018	0.09	0.024	0.01
	Constraint at t1--->grant large at t1	-0.026	0.046	0.577	-0.05	0.048	0.283	0.024	0.014	0.066
H1	Constraint at t1--->satisfaction with reputation of dept. and inst at t2	-0.034	0.04	0.371	-0.056	0.043	0.213	0.022	0.019	0.202
P3	Strong ties at t1-->superior ties at t1	0.391	0.062	0.01	0.391	0.062	0.01	...	...	...
P2	Strong ties at t1--->resources at t1	0.8	0.058	0.01	0.795	0.077	0.01	0.006	0.034	0.757
	Strong ties at t1--->awards at t1	0.085	0.053	0.111	-0.043	0.151	0.856	0.128	0.136	0.281
	Strong ties at t1--->salary at t1	0.139	0.055	0.023	0.307	0.565	0.058	-0.168	0.555	0.245
	Strong ties at t1--->grant large at t1	0.095	0.053	0.074	0.287	0.178	0.035	-0.191	0.164	0.117
H2a, H2b	Strong ties at t1--->satisfaction with reputation of dept. and inst at t2	-0.065	0.054	0.263	-0.087	0.526	0.462	0.022	0.516	0.747
P4	Superior ties at t1--->resources at t1	0.014	0.086	0.756	0.014	0.086	0.756	...	...	...
	Superior ties at t1--->awards at t1	0.029	0.06	0.647	0.027	0.064	0.681	0.002	0.021	0.796
	Superior ties at t1--->salary at t1	-0.458	0.067	0.01	-0.458	0.094	0.01	0	0.058	0.713
	Superior ties at t1--->grant large at t1	-0.122	0.063	0.067	-0.119	0.068	0.084	-0.003	0.023	0.863
H3a, H3b	Superior at t1-->satisfaction with reputation of dept. and inst at t2	-0.102	0.08	0.169	-0.109	0.116	0.185	0.008	0.088	0.831
	Resources at t1--->awards at t1	0.146	0.155	0.288	0.146	0.155	0.288	...	...	...
	Resources at t1--->salary at t1	0.013	0.529	0.867	0.013	0.529	0.867	...	...	...
	Resources at t1--->grant large at t1	-0.181	0.176	0.25	-0.181	0.176	0.25	...	...	...
H4	Resources at t1--->satisfaction with reputation of dept. and inst at t2	0.095	0.143	0.4	0.086	0.481	0.442	0.009	0.393	0.615
	Awards at t1--->satisfaction with reputation of dept. and inst at t2	0.007	0.039	0.863	0.007	0.039	0.863	...	...	...
	Salary at t1--->satisfaction with reputation of dept. and inst at t2	-0.003	0.074	0.947	-0.003	0.074	0.947	...	...	...
	Grant large at t1--->satisfaction with reputation of dept. and inst at t2	-0.042	0.039	0.331	-0.042	0.039	0.331	...	...	...
	Receipt of organizational resources--->satisfaction with reputation of dept. and inst at t2	-0.005	0.038	0.931	-0.005	0.038	0.931	...	...	...
	Number of publications at t1--->satisfaction with reputation of dept. and inst at t2	0.003	0.044	0.978	0.003	0.044	0.978	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with reputation of dept. and inst at t2	-0.031	0.039	0.306	-0.031	0.039	0.306	...	...	...
	Department faculty size--->satisfaction with reputation of dept. and inst at t2	0.004	0.038	0.768	0.004	0.038	0.768	...	...	...
	Female--->satisfaction with reputation of dept. and inst at t2	-0.027	0.037	0.504	-0.027	0.037	0.504	...	...	...
	South or southeast asian--->satisfaction with reputation of dept. and inst at t2	-0.047	0.039	0.234	-0.047	0.039	0.234	...	...	...
	Black/African American--->satisfaction with reputation of dept. and inst at t2	0.065	0.036	0.072	0.065	0.036	0.072	...	...	...
	Hispanic--->satisfaction with reputation of dept. and inst at t2	0.014	0.036	0.704	0.014	0.036	0.704	...	...	...
	Assistant Professor--->satisfaction with reputation of dept. and inst at t2	-0.025	0.072	0.736	-0.025	0.072	0.736	...	...	...
	Associate Professor--->satisfaction with reputation of dept. and inst at t2	-0.021	0.053	0.69	-0.021	0.053	0.69	...	...	...
	Physics--->satisfaction with reputation of dept. and inst at t2	0.038	0.048	0.476	0.038	0.048	0.476	...	...	...
	Chemistry--->satisfaction with reputation of dept. and inst at t2	0.01	0.045	0.938	0.01	0.045	0.938	...	...	...
	EAS-->satisfaction with reputation of dept. and inst at t2	0.094	0.047	0.05	0.094	0.047	0.05	...	...	...
	CS--->satisfaction with reputation of dept. and inst at t2	0.089	0.047	0.087	0.089	0.047	0.087	...	...	...
	EE--->satisfaction with reputation of dept. and inst at t2	0.013	0.047	0.835	0.013	0.047	0.835	...	...	...
	satisfaction with reputation of dept. and inst at t1--->satisfaction with reputation of dept. and ins	0.664	0.034	0.01	0.664	0.034	0.01	...	...	...

Table 7. Total, direct, and indirect effects without weights (predicting satisfaction with rewards at t2, with rewards at t2, without satisfaction with rewards at t1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint--->superior ties	-0.181	0.046	0.012	-0.181	0.046	0.012	...	...	...
	Constraint--->resources	-0.011	0.012	0.338	...	...	...	-0.011	0.012	0.338
	Constraint--->salary at t2	0.047	0.04	0.207	-0.003	0.043	0.998	0.05	0.015	0.013
	Constraint--->grant large at t2	0.033	0.045	0.526	0.012	0.047	0.844	0.021	0.011	0.03
H1	Constraint--->satisfaction with rewards at t2	-0.038	0.046	0.394	-0.02	0.046	0.669	-0.018	0.023	0.418
P3	Strong ties-->superior ties	0.329	0.061	0.01	0.329	0.061	0.01	...	...	...
P2	Strong ties--->resources	0.771	0.045	0.01	0.771	0.049	0.01	0.02	0.019	0.328
	Strong ties--->salary at t2	0.109	0.053	0.033	0.109	0.123	0.322	-0.004	0.103	0.941
	Strong ties--->grant large at t2	0.061	0.05	0.213	0.061	0.127	0.416	-0.031	0.108	0.729
H2a, H2b	Strong ties--->satisfaction with rewards at t2	-0.092	0.07	0.184	-0.092	0.154	0.282	0.056	0.114	0.647
P4	Superior ties--->resources	0.059	0.057	0.328	0.059	0.057	0.328	...	...	...
	Superior ties--->salary at t2	-0.279	0.052	0.01	-0.286	0.054	0.01	0.007	0.014	0.536
	Superior ties--->grant large at t2	-0.117	0.053	0.02	-0.118	0.054	0.02	0.001	0.011	0.999
H3a,H3b	Superior ties--->satisfaction with rewards at t2	0.095	0.106	0.375	0.121	0.108	0.293	-0.026	0.021	0.226
	Resources--->salary at t2	0.117	0.131	0.319	0.117	0.131	0.319	...	...	...
	Resources--->grant large at t2	0.01	0.134	0.93	0.01	0.134	0.93	...	...	...
H4	Resources--->satisfaction with rewards at t2	0.019	0.137	0.897	0.007	0.137	0.932	0.012	0.018	0.398
	Salary at t2--->satisfaction with rewards at t2	0.105	0.055	0.068	0.105	0.055	0.068	...	...	...
	Grant large at t2--->satisfaction with rewards at t2	-0.021	0.044	0.473	-0.021	0.044	0.473	...	...	...
	Receipt of organizational resources--->satisfaction with rewards at t2	0.127	0.046	0.01	0.127	0.046	0.01	...	...	...
	Number of publications at t1--->satisfaction with rewards at t2	0.07	0.058	0.221	0.07	0.058	0.221	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with rewards at t2	-0.05	0.048	0.409	-0.05	0.048	0.409	...	...	...
	Dept faculty size--->satisfaction with rewards at t2	0.008	0.047	0.894	0.008	0.047	0.894	...	...	...
	Female--->satisfaction with rewards at t2	-0.063	0.047	0.204	-0.063	0.047	0.204	...	...	...
	South or southeast asian--->satisfaction with rewards at t2	-0.054	0.046	0.234	-0.054	0.046	0.234	...	...	...
	Black/African American--->satisfaction with rewards at t2	0.095	0.045	0.03	0.095	0.045	0.03	...	...	...
	Hispanic--->satisfaction with rewards at t2	0.033	0.05	0.513	0.033	0.05	0.513	...	...	...
	Assistant Professor--->satisfaction with rewards at t2	-0.172	0.101	0.088	-0.172	0.101	0.088	...	...	...
	Associate Professor--->satisfaction with rewards at t2	-0.17	0.063	0.01	-0.17	0.063	0.01	...	...	...
	Physics--->satisfaction with rewards at t2	0.012	0.059	0.889	0.012	0.059	0.889	...	...	...
	Chemistry--->satisfaction with rewards at t2	0.007	0.06	0.896	0.007	0.06	0.896	...	...	...
	EAS-->satisfaction with rewards at t2	0.069	0.069	0.387	0.069	0.069	0.387	...	...	...
	CS--->satisfaction with rewards at t2	0.089	0.057	0.118	0.089	0.057	0.118	...	...	...
	EE--->satisfaction with rewards at t2	0.026	0.055	0.631	0.026	0.055	0.631	...	...	...

Table 8. Total, direct, and indirect effects without weights (predicting satisfaction with rewards at t2, with rewards at t1, without satisfaction with rewards at t1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint--->superior ties	-0.141	0.045	0.01	-0.141	0.045	0.01	...	...	...
	Constraint--->resources	0.002	0.011	0.815	...	...	...	0.002	0.011	0.815
	Constraint--->awards at t1	-0.034	0.049	0.53	-0.032	0.049	0.57	-0.002	0.008	0.813
	Constraint--->salary at t1	-0.015	0.046	0.801	-0.077	0.05	0.183	0.062	0.022	0.01
	Constraint--->grant large at t1	-0.016	0.049	0.786	-0.033	0.05	0.574	0.016	0.01	0.019
H1	Constraint--->satisfaction with rewards at t2	-0.015	0.05	0.81	0.028	0.053	0.595	-0.043	0.025	0.041
P3	Strong ties-->superior ties	0.405	0.058	0.01	0.405	0.058	0.01	...	...	...
P2	Strong ties--->resources	0.783	0.053	0.01	0.788	0.069	0.01	-0.005	0.032	0.815
	Strong ties--->awards at t1	0.099	0.055	0.085	0.008	0.136	0.982	0.091	0.113	0.334
	Strong ties--->salary at t1	0.112	0.054	0.043	0.219	0.161	0.139	-0.107	0.134	0.283
	Strong ties--->grant large at t1	0.094	0.054	0.096	0.258	0.178	0.028	-0.165	0.169	0.156
H2a, H2b	Strong ties--->satisfaction with rewards at t2	-0.074	0.065	0.239	-0.227	0.18	0.189	0.153	0.149	0.234
P4	Superior ties--->resources	-0.012	0.076	0.815	-0.012	0.076	0.815	...	...	...
	Superior ties--->awards at t1	0.015	0.057	0.814	0.017	0.059	0.811	-0.001	0.015	0.923
	Superior ties--->salary at t1	-0.44	0.063	0.01	-0.439	0.064	0.01	-0.001	0.012	0.943
	Superior ties--->grant large at t1	-0.115	0.056	0.017	-0.116	0.063	0.023	0.002	0.024	0.769
H3a,H3b	Superior ties--->satisfaction with rewards at t2	0.211	0.119	0.084	0.295	0.13	0.018	-0.084	0.039	0.01
	Resources--->awards at t1	0.108	0.134	0.338	0.108	0.134	0.338	...	...	...
	Resources--->salary at t1	0.09	0.144	0.538	0.09	0.144	0.538	...	...	...
	Resources--->grant large at t1	-0.15	0.18	0.237	-0.15	0.18	0.237	...	...	...
H4	Resources--->satisfaction with rewards at t2	0.046	0.141	0.766	0.023	0.149	0.883	0.024	0.033	0.462
	Awards at t1--->satisfaction with rewards at t2	-0.018	0.043	0.617	-0.018	0.043	0.617	...	...	...
	Salary at t1--->satisfaction with rewards at t2	0.202	0.057	0.01	0.202	0.057	0.01	...	...	...
	Grant large at t1--->satisfaction with rewards at t2	-0.049	0.048	0.323	-0.049	0.048	0.323	...	...	...
	Receipt of organizational resources--->satisfaction with rewards at t2	0.081	0.045	0.101	0.081	0.045	0.101	...	...	...
	Number of publications at t1--->satisfaction with rewards at t2	0.044	0.052	0.361	0.044	0.052	0.361	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with rewards at t2	0.009	0.049	0.822	0.009	0.049	0.822	...	...	...
	Dept faculty size--->satisfaction with rewards at t2	0.026	0.045	0.538	0.026	0.045	0.538	...	...	...
	Female--->satisfaction with rewards at t2	-0.105	0.046	0.052	-0.105	0.046	0.052	...	...	...
	South or southeast asian--->satisfaction with rewards at t2	-0.058	0.042	0.234	-0.058	0.042	0.234	...	...	...
	Black/African American--->satisfaction with rewards at t2	0.109	0.05	0.02	0.109	0.05	0.02	...	...	...
	Hispanic--->satisfaction with rewards at t2	0.028	0.046	0.504	0.028	0.046	0.504	...	...	...
	Assistant Professor--->satisfaction with rewards at t2	-0.219	0.089	0.017	-0.219	0.089	0.017	...	...	...
	Associate Professor--->satisfaction with rewards at t2	-0.185	0.058	0.01	-0.185	0.058	0.01	...	...	...
	Physics--->satisfaction with rewards at t2	-0.006	0.06	0.808	-0.006	0.06	0.808	...	...	...
	Chemistry--->satisfaction with rewards at t2	-0.042	0.067	0.588	-0.042	0.067	0.588	...	...	...
	EAS-->satisfaction with rewards at t2	0.059	0.064	0.349	0.059	0.064	0.349	...	...	...
	CS--->satisfaction with rewards at t2	0.063	0.055	0.232	0.063	0.055	0.232	...	...	...
	EE--->satisfaction with rewards at t2	0.001	0.054	0.967	0.001	0.054	0.967	...	...	...

Table 9. Total, direct, and indirect effects w/o weights (predicting satisfaction with reputation at t2, with rewards at t2, without satisfaction with reputation at t1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint--->superior ties	-0.164	0.048	0.01	-0.164	0.048	0.01	...	...	...
	Constraint--->resources	-0.014	0.013	0.281	...	...	...	-0.014	0.013	0.281
	Constraint--->salary at t2	0.065	0.043	0.159	0.015	0.048	0.802	0.051	0.018	0.01
	Constraint--->grant large at t2	0.042	0.049	0.405	0.029	0.05	0.568	0.013	0.011	0.216
H1	Constraint--->satisfaction with reputation of dept. and inst at t2	-0.016	0.052	0.701	-0.047	0.055	0.347	0.031	0.018	0.044
P3	Strong ties-->superior ties	0.299	0.064	0.01	0.299	0.064	0.01	...	...	...
P2	Strong ties--->resources	0.756	0.047	0.01	0.731	0.055	0.01	0.026	0.022	0.28
	Strong ties--->salary at t2	0.178	0.05	0.01	0.264	0.122	0.031	-0.087	0.104	0.346
	Strong ties--->grant large at t2	0.048	0.053	0.397	0.093	0.118	0.423	-0.045	0.093	0.71
H2a, H2b	Strong ties--->satisfaction with reputation of dept. and inst at t2	0.03	0.066	0.634	0.042	0.116	0.732	-0.012	0.085	0.962
P4	Superior ties--->resources	0.087	0.071	0.281	0.087	0.071	0.281	...	...	...
	Superior ties--->salary at t2	-0.308	0.056	0.01	-0.309	0.058	0.01	0.001	0.013	0.879
	Superior ties--->grant large at t2	-0.079	0.06	0.217	-0.076	0.064	0.28	-0.003	0.014	0.903
H3a,H3b	Superior ties--->satisfaction with reputation of dept. and inst at t2	-0.19	0.089	0.045	-0.184	0.091	0.062	-0.006	0.023	0.729
	Resources--->salary at t2	0.008	0.13	0.978	0.008	0.13	0.978	...	...	...
	Resources--->grant large at t2	-0.029	0.124	0.888	-0.029	0.124	0.888	...	...	...
H4	Resources--->satisfaction with reputation of dept. and inst at t2	0.051	0.108	0.593	0.05	0.108	0.631	0.002	0.011	0.947
	Salary at t2--->satisfaction with reputation of dept. and inst at t2	0.043	0.059	0.391	0.043	0.059	0.391	...	...	...
	Grant large at t2--->satisfaction with reputation of dept. and inst at t2	-0.04	0.038	0.329	-0.04	0.038	0.329	...	...	...
	Receipt of organizational resources--->satisfaction with reputation of dept. and inst at t2	0.067	0.045	0.114	0.067	0.045	0.114	...	...	...
	Number of publications at t1--->satisfaction with reputation of dept. and inst at t2	0.064	0.041	0.129	0.064	0.041	0.129	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with reputation of dept. and inst at t2	-0.09	0.043	0.035	-0.09	0.043	0.035	...	...	...
	Dept faculty size--->satisfaction with reputation of dept. and inst at t2	0.185	0.047	0.01	0.185	0.047	0.01	...	...	...
	Female--->satisfaction with reputation of dept. and inst at t2	-0.027	0.04	0.584	-0.027	0.04	0.584	...	...	...
	South or southeast asian--->satisfaction with reputation of dept. and inst at t2	0.019	0.043	0.696	0.019	0.043	0.696	...	...	...
	Black/African American--->satisfaction with reputation of dept. and inst at t2	0.071	0.039	0.081	0.071	0.039	0.081	...	...	...
	Hispanic--->satisfaction with reputation of dept. and inst at t2	-0.021	0.048	0.737	-0.021	0.048	0.737	...	...	...
	Assistant Professor--->satisfaction with reputation of dept. and inst at t2	-0.039	0.076	0.586	-0.039	0.076	0.586	...	...	...
	Associate Professor--->satisfaction with reputation of dept. and inst at t2	-0.053	0.047	0.285	-0.053	0.047	0.285	...	...	...
	Physics--->satisfaction with reputation of dept. and inst at t2	0.003	0.049	0.952	0.003	0.049	0.952	...	...	...
	Chemistry--->satisfaction with reputation of dept. and inst at t2	0.04	0.052	0.461	0.04	0.052	0.461	...	...	...
	EAS-->satisfaction with reputation of dept. and inst at t2	0.197	0.06	0.01	0.197	0.06	0.01	...	...	...
	CS--->satisfaction with reputation of dept. and inst at t2	0.004	0.055	0.938	0.004	0.055	0.938	...	...	...
	EE--->satisfaction with reputation of dept. and inst at t2	0.017	0.046	0.71	0.017	0.046	0.71	...	...	...

Table 10. Total, direct, and indirect effects w/o weights (predicting satisfaction with reputation at t2, with rewards at t1, without satisfaction with reputation at t1)

		Total effects			Direct effects			Indirect effects		
		Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.	Std. Est.	S.E	Sig.
P1	Constraint at t1--->superior ties at t1	-0.197	0.048	0.01	-0.197	0.048	0.01	...	...	...
	Constraint at t1--->resources at t1	-0.002	0.016	0.935	...	...	...	-0.002	0.016	0.935
	Constraint at t1--->awards at t1	-0.06	0.043	0.129	-0.055	0.043	0.163	-0.005	0.012	0.626
	Constraint at t1--->salary at t1	-0.029	0.042	0.442	-0.119	0.045	0.018	0.09	0.024	0.01
	Constraint at t1--->grant large at t1	-0.025	0.045	0.535	-0.05	0.046	0.259	0.024	0.014	0.048
H1	Constraint at t1--->satisfaction with reputation of dept. and inst at t2	0.002	0.048	0.945	-0.035	0.054	0.468	0.036	0.027	0.18
P3	Strong ties at t1-->superior ties at t1	0.39	0.055	0.01	0.39	0.055	0.01	...	...	...
P2	Strong ties at t1--->resources at t1	0.812	0.065	0.01	0.808	0.079	0.01	0.004	0.031	0.934
	Strong ties at t1--->awards at t1	0.086	0.051	0.107	-0.053	0.214	0.667	0.139	0.196	0.227
	Strong ties at t1--->salary at t1	0.14	0.049	0.012	0.302	0.207	0.039	-0.162	0.184	0.198
	Strong ties at t1--->grant large at t1	0.096	0.052	0.04	0.304	0.289	0.04	-0.208	0.277	0.08
H2a, H2b	Strong ties at t1--->satisfaction with reputation of dept. and inst at t2	0.018	0.073	0.983	0.101	0.207	0.589	-0.083	0.172	0.558
P4	Superior ties at t1--->resources at t1	0.011	0.079	0.935	0.011	0.079	0.935	...	...	...
	Superior ties at t1--->awards at t1	0.027	0.058	0.626	0.025	0.061	0.676	0.002	0.019	0.867
	Superior ties at t1--->salary at t1	-0.456	0.061	0.01	-0.456	0.061	0.01	0	0.015	0.768
	Superior ties at t1--->grant large at t1	-0.123	0.058	0.045	-0.121	0.061	0.057	-0.002	0.024	0.973
H3a, H3b	Superior at t1-->satisfaction with reputation of dept. and inst at t2	-0.217	0.109	0.036	-0.201	0.118	0.096	-0.016	0.03	0.699
	Resources at t1--->awards at t1	0.159	0.211	0.299	0.159	0.211	0.299	...	...	...
	Resources at t1--->salary at t1	0.02	0.191	0.915	0.02	0.191	0.915	...	...	...
	Resources at t1--->grant large at t1	-0.198	0.294	0.221	-0.198	0.294	0.221	...	...	...
H4	Resources at t1--->satisfaction with reputation of dept. and inst at t2	0	0.167	0.956	-0.015	0.182	0.96	0.015	0.032	0.412
	Awards at t1--->satisfaction with reputation of dept. and inst at t2	0.045	0.046	0.312	0.045	0.046	0.312	...	...	...
	Salary at t1--->satisfaction with reputation of dept. and inst at t2	0.048	0.056	0.442	0.048	0.056	0.442	...	...	...
	Grant large at t1--->satisfaction with reputation of dept. and inst at t2	-0.036	0.045	0.428	-0.036	0.045	0.428	...	...	...
	Receipt of organizational resources--->satisfaction with reputation of dept. and inst at t2	0.05	0.05	0.285	0.05	0.05	0.285	...	...	...
	Number of publications at t1--->satisfaction with reputation of dept. and inst at t2	0.027	0.049	0.453	0.027	0.049	0.453	...	...	...
	Number of courses taught or co taught at t1--->satisfaction with reputation of dept. and inst at t2	-0.077	0.042	0.123	-0.077	0.042	0.123	...	...	...
	Department faculty size--->satisfaction with reputation of dept. and inst at t2	0.168	0.05	0.01	0.168	0.05	0.01	...	...	...
	Female--->satisfaction with reputation of dept. and inst at t2	-0.045	0.044	0.392	-0.045	0.044	0.392	...	...	...
	South or southeast asian--->satisfaction with reputation of dept. and inst at t2	0.009	0.044	0.8	0.009	0.044	0.8	...	...	...
	Black/African American--->satisfaction with reputation of dept. and inst at t2	0.074	0.042	0.133	0.074	0.042	0.133	...	...	...
	Hispanic--->satisfaction with reputation of dept. and inst at t2	-0.006	0.047	0.989	-0.006	0.047	0.989	...	...	...
	Assistant Professor--->satisfaction with reputation of dept. and inst at t2	-0.001	0.083	0.994	-0.001	0.083	0.994	...	...	...
	Associate Professor--->satisfaction with reputation of dept. and inst at t2	-0.064	0.058	0.391	-0.064	0.058	0.391	...	...	...
	Physics--->satisfaction with reputation of dept. and inst at t2	0.002	0.054	0.948	0.002	0.054	0.948	...	...	...
	Chemistry--->satisfaction with reputation of dept. and inst at t2	0.026	0.058	0.7	0.026	0.058	0.7	...	...	...
	EAS-->satisfaction with reputation of dept. and inst at t2	0.191	0.068	0.01	0.191	0.068	0.01	...	...	...
	CS--->satisfaction with reputation of dept. and inst at t2	0.026	0.057	0.617	0.026	0.057	0.617	...	...	...
	EE--->satisfaction with reputation of dept. and inst at t2	0.039	0.052	0.388	0.039	0.052	0.388	...	...	...

VITA

NAME: Yamini Jha

EDUCATION: B.A., Delhi University, 1998
M.A., Geography, Delhi University, 2000
M.A., Regional Planning, School of Planning, Delhi University, 2002
PhD., Public Administration University of Illinois, Chicago, 2013.

ACADEMIC WORK EXPERIENCE: Science, Technology, and Environment Policy Lab, Department of Public Administration, University of Illinois at Chicago.

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AWARDS: Invited to Doctoral Consortium, Academy of Management, 2009

PUBLICATIONS: Jha, Y, & Eric Welch. (2010). Relational mechanisms governing multifaceted collaborative behavior of academic scientists in six fields of science and engineering. 39(9).