Two essays on the origins of academic collaborative networks

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**NANYANG
TECHNOLOGICAL
UNIVERSITY**

**TWO ESSAYS ON THE ORIGINS OF ACADEMIC
COLLABORATIVE NETWORKS**

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2016

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COLLABORATIVE NETWORKS**

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I dedicate this work to

Mom & Dad

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ABSTRACT

Social networks play a critical role in knowledge creation and transfer. While a large and growing body of research has provided significant evidence on how social relationships and the networks they constitute affect the efficacy and efficiency of knowledge exchange and creation, little is known about how social networks are formed, and empirical work is particularly lacking. Using data on samples of academic scholars, this dissertation aims to investigate the origins of academic collaborative networks.

This dissertation consists of two essays. In the first essay, I examine how the formation of collaborative networks is influenced by the joint effects of organizational setting and individual productivity in the early career of academic scholars. From the structural perspective, I argue that since institutions provide opportunities or constraints for their members to form certain ties, academic scholars affiliated in institutions of varying prestige are likely to exhibit different internal and external collaborative networks. The findings provide support for this view, showing that the higher the prestige of the institution where the scholars secured their employment, the more attention they will allocate to forming external ties and the sparser the internal network they will have. Furthermore, incorporating an agentic view, I highlight that individuals can be active agents in orchestrating their social networks within the constraints of the resources available in their work organizations. The findings

show that individuals' productivity moderated the effects of institutional prestige on scholars' collaborative networks, in particular with regard to their internal network structure. Contrary to my expectation, less productive scholars are actually more motivated to actively appropriate the non-redundant knowledge and opportunities within prestigious institutions by cultivating sparse internal networks.

In the second essay, I focus on how individuals' internal knowledge structures influence the formation of new ties, and how the number of new ties mediates the effect of knowledge structure on knowledge acquisition. Integrating cognitive and social network perspectives, I argue that individuals' pre-existing knowledge can influence their capacity to absorb from and transfer knowledge to potential partners, thereby affecting the likelihood of an initial encounter to become a successful collaboration. The results show that knowledge breadth is positively associated with the amount of new ties one forms, and that knowledge depth is curvilinearly related to the amount of new ties one forms assuming an inverted U shape. In addition, I find that new ties partially mediate the relationship between knowledge depth and knowledge acquisition. These findings suggest that there can be bidirectional dynamics between individual knowledge and network formation such that people with adequate knowledge breadth and depth are more apt to form new ties, which in turn will lead to more new knowledge.

Overall, connecting social network perspective with human agency and cognitive perspectives, this research sheds light on how individual collaborative networks are formed.

CHAPTER 1

Overview of the Dissertation

Social networks play a critical role in knowledge creation and transfer. A large and growing body of empirical research has shown that different features of social relationships and the networks these relationships constitute significantly influence the processes of knowledge creation, diffusion, absorption, and adoption (e.g., (Burt, 2004; Hansen, 1999; McFadyen & Cannella, 2004; Reagans & McEvily, 2003). For example, focusing on the structural dimensions of networks, some scholars found that structural holes enhance individual knowledge creation (Burt, 2004; Fleming, Mingo, & Chen, 2007; McFadyen, Semadeni, & Cannella, 2009), while other scholars found that network density promotes knowledge transfer among network contacts and improves learning (Morgan & Sørensen, 1999; Morrison, 2002; Reagans & McEvily, 2003). Taking a relational perspective of networks, studies have shown that weak ties facilitate individual creativity because weak ties contains more non-redundant information (Perry-Smith, 2006), while strong interpersonal ties are more effective in enhancing the transfer of tacit and complex knowledge (Hansen, 1999; Hansen, Mors, & Løvås, 2005).

While this stream of research has provided significant evidence as to the importance of social networks to knowledge creation and transfer, little is known about how networks are formed, and empirical work is particularly

lacking. Classic works have theorized two broad forces that drive changes in social network ties (Ahuja, Soda, & Zaheer, 2012; Zaheer & Soda, 2009). One is structural enablers and constraints that induce opportunities, social norms or habits that influence how individuals behave toward their social network relations (e.g., (Kossinets & Watts, 2009; Zaheer & Soda, 2009). Structure, in this perspective, cover a wide theoretical terrain including not only existing social network structure but also organized social setting that affect social interactions. The other is human agency, which emphasizes the focal actor's motivation and ability to shape relations. In this view, actors deliberately seek to create a beneficial link or dissolve an unprofitable one according to their homophilous (McPherson, Smith-Lovin, & Cook, 2001; Reagans, 2011) or heterophilous preferences (Moody, 2004; Rivera, Soderstrom, & Uzzi, 2010).

In this dissertation, I incorporate the agentic perspective to investigate the origins of collaborative networks. I highlight that individuals help shape the social networks they inhabit. While most of prior research has focused on how individual demographic or psychological traits influence their choices of network ties and network structures, I examine another dimension of individual characteristics – human capital. Human capital factors such as individual productivity and knowledge stock are particularly relevant in the formation of professional collaborative networks for three reasons. First, more productive individuals are likely to be motivated to select collaborative ties that generate greater returns as they pursue their career goals. Second, individuals who are more productive or have substantial knowledge stock are more likely to be

regarded as higher-quality actors, and thus enjoy more opportunities to form new ties. Third, from the perspective of absorptive capacity, actors with diverse and deep knowledge have higher capacity to absorb from and transfer knowledge to others, thereby enhancing their ability to form collaborative ties.

In particular, I examine how the formation of collaborative networks is influenced by the joint effects of organizational setting and individual productivity in the first essay, and the structure of individual knowledge stock in the second essay, as reported in the next two chapters.

In Chapter 2, I examine how institutional prestige influences academic scholars' collaborative ties in their early career, and to what extent scholars can be agentic in their collaborative network choices. From the structural perspective, I argue that since institutions provide opportunities or constraints for their members to form certain ties, academic scholars affiliated in institutions of varying prestige are likely to exhibit different internal and external collaborative networks. The findings provide support for this view, showing that the higher the prestige of the institution where the scholars secured their employment, the more attention they will allocate to forming external ties and the sparser the internal network they will have. Furthermore, incorporating an agentic view, I highlight that individuals can be active agents in orchestrating their social networks within the constraints of the resources available in their work organizations. The findings show that individual productivity moderates the effects of institutional prestige on scholars' collaborative networks, in particular with regard to their internal network

structure. Contrary to my expectation, less productive scholars are actually more motivated to actively appropriate the non-redundant knowledge and opportunities within prestigious institutions by cultivating sparse internal networks.

In Chapter 3, I focus on how individuals' internal knowledge structure influences the formation of new ties and how the number of new ties mediates the effect of knowledge structure on knowledge acquisition. Integrating cognitive and social network perspectives, I argue that individuals' pre-existing knowledge can influence their capacity to absorb new information from and transfer knowledge to potential partners, thereby affecting the likelihood of an initial encounter to become a successful collaboration. The results show that knowledge breadth is positively associated with the amount of new ties one forms, and that knowledge depth is curvilinearly related to the amount of new ties one forms assuming an inverted U shape. In addition, I find that new ties partially mediate the relationship between knowledge depth and knowledge acquisition. This is consistent with the argument that by forming more new ties, scholars are advantaged in getting access to more new information, thus fostering their acquisition of new knowledge.

In both studies, I use samples of academic scholars to test my hypotheses. Goals and work of academia revolves around the integration and creation of knowledge. Scholarly publications are the main knowledge production of academic scholars, which provide a good source to study their collaborative networks. In addition, academic scholars frequently collaborate with others to

integrate their knowledge in the pursuit of new knowledge creation (Moody, 2004). In contrast to other occupations where collaborative ties tend to follow more rigid work procedures, academic scholars enjoy considerable leeway in their choices of collaborative research partners. These characteristics of the academic community establish an ideal setting to investigate the origins of collaborative networks.

This dissertation contributes to social network literature by demonstrating the important roles of individual differences in human capital factors, as a contingency factor or a direct predictor, in the formation of social networks.

First, while acknowledging the significant influence of social conditions on individuals' social networks, individuals differ in their motivation to actively appropriate the resources available in their organizations. As a contingency factor, individual differences will interact with social settings to affect individuals' collaborative networks. Consistent with this view, the findings provide evidence on the moderating role of individual productivity on the relationship between institutional prestige and individuals' collaborative networks.

Second, individual differences can be a direct predictor of network formation. Individuals differ in their cognitive ability to form new ties. Integrating cognitive and social network perspectives, I argue that individuals' pre-existing knowledge can influence their capacity to absorb from and transfer knowledge to potential partners, thereby affecting the likelihood of an initial encounter to become a successful collaboration. The findings demonstrate that

with other things being equal, individuals with adequate knowledge stock are more advantaged in forming new ties.

CHAPTER 2

Institutional Prestige, Individual Productivity and Academic Collaborative Networks in Early Career

INTRODUCTION

Organizational membership can influence individual social networks, since their joint activities foster social interactions. As a form of foci that brings people together – whether actively or passively – for joint activities, organizations structure interpersonal relationships in patterned ways (Feld, 1981); and have been used to explain the tendency for individuals to have homogeneous contacts (Feld, 1982; McPherson & Smith-Lovin, 1987). This idea reflects the premise that there is a duality between groups and individuals (Breiger, 1974). Individuals come together within groups, and at the same time, groups intersect within the person through the particular patterning of an individual's affiliations. The two are intricately intertwined in their effects on the other's relationships.

My study extends from this idea to examine how institutional prestige influences academic scholars' collaborative ties in their early career, and to what extent scholars can be agentic in their collaborative network choices. From a structural perspective, organizational structures locate individuals' actions in physical space and in workflows and hierarchies, restricting or

facilitating their opportunities to interact with others (Brass, Galaskiewicz, Greve, & Tsai, 2004; Dahlander & McFarland, 2013). Work organizations, as a form of formal foci, can affect individual social networks by channeling individuals' opportunities and energy toward rewarding social interactions (Brass, 1985; Feld, 1982; Ibarra, 1992, 1995). Accordingly, I expect that the opportunity set represented in organizations of varying prestige can predict variations in collaborative networks.

Furthermore, incorporating the agentic perspective, I argue that individuals can help shape the social networks they inhabit. Prior research has focused on three forces that may predispose individuals to form their social networks. One is the demographic trait. Homophily principle suggests that people prefer to interact with similar others. It has been demonstrated with respect to gender, age, social status, race, education, religion, occupation, and other demographics (see (McPherson et al., 2001), for a review). The second concerns psychological differences. Prior research has suggested that dispositional forces such as individual differences in personality can drive the social networks of individuals (e.g., (Burt, Jannotta, & Mahoney, 1998; Kalish & Robins, 2006; Sasovova, Mehra, Borgatti, & Schippers, 2010). For example, some studies found that high self-monitors are more likely to occupy central position in the social networks (Mehra, Kilduff, & Brass, 2001), and are also more motivated and skilled at acquiring new structural holes (Sasovova et al., 2010).

Besides demographic and personality traits, another dimension of individual characteristics – human capital – may also play a role in the

formation of social networks. Prior research provides circumstantial support for such phenomenon. A notable one is a study done by Lee (2010), which demonstrated that inventors with superior productivity records are more likely to occupy brokerage positions. Human capital factors such as individual productivity are particularly relevant in the formation of professional collaborative networks for two reasons. First, more productive individuals are more motivated to select collaborative ties that generate greater returns as they pursue their career goals. Second, more productive individuals are more likely to be regarded as higher-quality actors, and thus enjoy more opportunities to form new ties. Following this stream of work, I argue that despite the social structural opportunity (or constraint) posed by their work organizations, individuals are capable to take purposeful actions to appropriate the resources afforded by their structural conditions (Emirbayer & Goodwin, 1994). To the extent that individuals differ in their motivation and ability to actively appropriate the resources available within their organizations, more productive scholars are more motivated and apt to form efficient networks to acquire the opportunities and resources presented in prestigious institutions, relative to their less productive counterparts

I center my theoretical focus on one key social structural characteristic of work organizations – its prestige. Prior studies have focused on social structural predictors of social network patterns, such as organization size and organizational demography. For example, the homophily research has shown that sharing a demographic characteristic facilitates tie formation between

people (e.g., Ibarra, 1992, 1995; Tsui & O'reilly, 1989). Since my interest is not only in the structural antecedents but also the agentic choices of individual network partners within the opportunities and constraints present in the individual's work organization, I focus on organizational prestige – a social structural characteristic of organizations associated with varying levels of opportunities and resources available to its members (Crane, 1970; Long, 1978). Accordingly, it is likely that individuals' social networks would vary with the prestige of their organization due to the differing opportunities and resources. Moreover, if individuals differ in their motivation and ability to actively appropriate the resources available within their organizations, I would expect that differences in individual characteristics, such as productivity, moderate the effects of institutional prestige on scholars' collaborative networks.

To examine the relationship between institutional prestige, individual productivity and academic collaborative networks, I particularly focused on scholars' early career. In the early stage of academic career, under great pressure to publish, scholars are likely to be keen to proactively form collaborative ties. In addition, before they have a more established academic reputation or get promoted and tenure, the first few years in academia is a career stage where institutional prestige is likely to have a greater influence on the resources and opportunities that one could rely on to develop collaborative network. If academics in their early careers are more active in cultivating ties that are commensurate with the social structural opportunity (or constraint)

posed by their institution, then I would expect the institutional changes of academics to be followed by changes in their collaborative networks. Thus, I chose to examine the effects of the prestige of academic institution on academics' collaborative network after their appointment as an assistant professor.

To test my ideas, I selected academic scholars in the field of Management as my population since data on their collaborative research ties and organizational prestige of their work institution are widely available. In addition, there is robust evidence that the prestige of universities significantly affects the career success of academics (Allison & Long, 1990; Long, 1978), suggesting that varying prestige in one's organization of employment brings about differential amounts of resources that affects one's career prospects. In contrast to other occupations where collaborative ties tend to follow more rigid work procedures, academics in a discipline such as Management also typically enjoy freedom in their choices of collaborative research partners and, thus, will be a more appropriate sample for my research.

THEORETICAL BACKGROUND AND MODEL

Institutional Prestige

The prestige of an institution reflects its reputation and status in the stratification system of institutions.(e.g., Burris, 2004; Long, 1978). A variety of studies across different disciplines have evidenced that prestige of the

institution in which academics received their PhD or secured their employment is a key determinant of career prospects for academics (e.g., Allison, Long, & Krauze, 1982; Keith & Babchuk, 1994; Long, 1978; Long, Allison, & McGinnis, 1979; Long, Bowers, Barnett, & White, 1998; Merton, 1968; Reskin, 1977; Reskin, 1979; Williamson & Cable, 2003). A variety of causal mechanisms that explain the career-enhancing effects of academic prestige have been proposed.

First, the matched norms and values of prestigious institutions and their faculty toward research and production of scientific knowledge contribute to greater research productivity of the faculty (Long, Crawford, White, & Davis, 2009). High-status universities tend to be research-intensive in orientation since the research productivity of its faculty is a key driver of the reputation of the university within the academic community (Pfeffer, Leong, & Strehl, 1976). In line with the “person-organization fit” perspective (Chatman, 1989, 1991), and theories of attraction, selection, and attrition (Schneider, Goldstein, & Smith, 1995), scholars with strong research focus are likely to be attracted to research-oriented institutions and these institutions are likely to hire scholars with coincident norms and values. Similar to the “sacred spark” hypothesis (Cole & Cole, 1973), the inner drive of individuals attracted to prestigious universities motivates them to conduct research and, thus, achieve greater career success through higher research productivity. To the extent that the research-orientation of prestigious institutions socialize their faculty to place greater value on the production of scientific knowledge (Reskin, 1977) or offer greater extrinsic

rewards for research productivity such as pay raises, tenure, and promotion (Konrad & Pfeffer, 1990; Pfeffer, 1993), then behaviors toward the pursuit of higher research productivity is reinforced.

Second, institutions of higher social standing are believed to offer more resources required for research productivity such as release time from teaching, research funding, research assistants, and research facilities (D'Aveni, 1996). Since more prestigious universities also tend to have a larger pool of faculty (Haestrom, 1971), these universities would also provide access to more intellectual resources and research opportunities – both valuable for career success in academia.

Third, a well-documented mechanism stems from the “Matthew Effect” (Merton, 1968; Merton, 1988). This effect refers to the greater recognition eminent scholars receive than a comparatively unknown researcher, even if their work is similar in quality. Compared with scholars from lower-status institutions, those from higher-status institutions can be perceived as producing higher-quality research and, as a result, are more likely to receive greater attention and recognition from their publications. In effect, affiliation with a high-status institution can cast a “halo” over a scholar’s work, whereby his or her research papers and grant proposals appear more impressive to reviewers and to potential citers. For instance, the prestige of a scholar’s institutional affiliation might influence editors’ choices of reviewers or peers’ citation choices.

Finally, one can also expect the higher social centrality of more prestigious institutions in the inter-institutional PhD hiring and placement network to yield greater social capital to its faculty (Burris, 2004). As the higher centrality of a more prestigious institution in the PhD exchange network suggests that the institution has developed an extensive network of ties to scholars within the discipline, one can expect that faculty of these institutions are advantaged in securing collegial recognition in their field, namely, obtaining endorsements or nominations in professional associations, editorial boards, invited lectures and so on.

In summary, the research on academic prestige provides insights into how membership in a more prestigious institution translates to individual advantages via the creation of psychological resources (e.g., individual motivation), economic resources (e.g., research funding and other financial supports), intellectual resources (e.g., ideas and expertise), reputational resources (i.e., halo effect), and social resources (e.g., endorsement). Despite the purported availability of this rich array of resources to academics at prestigious institutions, few studies have investigated how it will affect academics' collaborative networks.

Social Networks: Internal Networks vs. External Networks

A rich body of work has emerged to demonstrate that social networks play a significant role in knowledge search and research output for academic scholars and scientists. Theoretical attention has been on the structural and relational dimensions of a scholar's network. For example, focusing on the

structural dimensions of networks, some researchers found that structural holes have a positive effect on individual knowledge creation (e.g., (Burt, 2004; McFadyen, Semadeni, & Cannella, 2009), while other scholars demonstrated that network closure promotes the adoption of an inventor's novel idea (Fleming, Mingo, & Chen, 2007). From a relational perspective of networks, studies have shown that weak ties promote creativity (Perry-Smith, 2006; Perry-Smith & Shalley, 2003), while strong interpersonal ties are more effective in enhancing knowledge transfer and learning (e.g., (Bouty, 2000; Levin & Cross, 2004; Uzzi & Lancaster, 2003).

While these empirical studies are illuminating, few studies have investigated another key network dimension – internal vs. external networks, and its impacts on knowledge search and research output for academic scholars and scientists. One exception is the study done by He, Geng and Campbell-Hunt (2009). They distinguished between international collaboration, domestic collaboration, and within-university collaboration, and found that at article level, both within-university collaboration and international collaboration are positively related to an article's quality and that, at scientist-year level, only international collaboration is positively related to a scientist's future research output. Their results suggest that the social capital embedded in the networks within and outside of one's institute can be different. Moreover, as I am interested in the origin of a scholar's network formation, it is reasonable to expect that an individual would adopt different strategies to leverage the benefits that are embedded in various networks.

Hence, in the present study, I distinguish between a scholar's external network and internal network in terms of spatial distance. Specifically, a scholar's internal network is comprised of his or her collaborators within a same home institute, while external network ties refer to partners beyond one's home institute. Collaboration with partners at different distance ranges may have implications on communication cost and knowledge non-redundancy. On the one hand, communication with internal ties is easier due to co-location advantage and regular day-to-day contact. Collocated coworkers are more likely to frequently interact with each other and develop a common language of discourse. However, internal collaboration has limited scope for knowledge transfer, as internal ties who share the same physical space are more likely to circulate redundant information. On the other hand, external collaboration can "plug" a scholar into a much wider research network and provide access to different experience and non-redundant knowledge. Nonetheless, collaboration with external partners is likely to incur higher cost, especially in terms of coordinating research carried out at geographically dispersed locations and possibly extra time and expense for travelling and visiting (He et al., 2009). Given the different features of internal ties and external ties, I argue that scholars would adopt different strategies when forming internal ties and external ties to best leverage the benefits one can derive from his or her network.

Proportion of External Ties

Faculty members from institutions of high status are advantaged in participating in across-boundary collaborations that are often thought to be costly to form and maintain. The ability of scholar to develop network connections is believed to vary with distance. In fact, Katz (1994) found that the likelihood of co-authorship decreases exponentially with the distance separating pairs of partners. Indeed, spatial distance reduces the probability of informal communication, which, in turn, leads to less network relationships. However, scholars from prestigious schools can benefit from their institutional reputation in forming external network ties in three ways. First, mere affiliation to a prestigious institution can bring reputational gains in the form of enhanced visibility and the halo effect of aptitude, as members “basked in reflected glory” of the prior successes of their groups (Cialdini et al., 1976). The initial attention advantage can contribute to greater subsequent reputational gain when others pay disproportionate attention to research performed by scholars with greater initial reputation (Merton, 1968). Hence, scholars from prestigious university are usually regarded as high-performing actors, and thus they are more likely to be actively pursued by potential external partners or be invited to external seminars or conferences. Second, prestigious institutes have more chances to host international or regional events that would bring scholars from other schools or institutes together to exchange research ideas. In addition, collaborations with external partners require more investment in time and coordination efforts. Scholars from prestigious institutes are likely to enjoy

more research leaves as well as financial support for travelling, which make regular visit to an external institute possible. Therefore, despite of the spatial distance from external contacts, scholars from prestigious institutions not only attract more partners from outside, but also enjoy more opportunities to engage in formal or informal communication with potential collaborators in various occasions, which reduce the cost of forming external network relationships.

Given the advantages one can gain from his or her institutional prestige in partaking in across-boundary exchange, I argue that the scholar will form more external ties out of the total number of his or her network ties. There is a finite number of ties an individual can credibly maintain (Jackson, 2008), because each tie requires attention, and individuals have limited attention to distribute (March & Simon, 1958). To the extent that one can only maintain a finite number of ties, individuals have to locate their time and attention efficiently and select among different credible options (Dahlander & McFarland, 2013; Simon, 1971). External ties that cut across formal organizational boundaries are valuable to academic scholars, because distant partners are more likely to introduce ideas and techniques that are novel and non-overlapping for a scholar to learn (Burt, 1992). Compared with external ties, local partners who share the same physical space are more likely to possess redundant information and provide little additional information over what an individual may already know (Granovetter, 1973; Granovetter, 1983). Even though on average faculty members from more prestigious institute may have larger collaborative networks due to more research time and resources, they are likely to invest in

more external ties rather than internal ties, because each external tie can provide access to non-redundant knowledge located outside the focal institute while the information capital brought by an additional internal tie could only be marginal. Hence, to gather non-redundant information, a scholar from more prestigious institutions will utilize the reputational resources and across-boundary exchange opportunities to form more external ties out of the total number of his or her network ties.

In contrast, in less prestigious institutions where the institutional reputation effect is absent and the economic and financial support is less, scholars have to spend additional time and effort to develop and maintain external collaborations. In this situation, the external information capital is acquired at great cost, such as sacrificing the time that they could have spent in reading, writing or running experiments. When the cost of forming external ties outweighs its benefit, scholars will instead focus more of their attention on cultivating internal collaborations. In such case, accessing knowledge from co-located colleagues who share the same physical space and the same language of discourse is more efficient, economizing on the amount and intensity of communication needed to achieve knowledge integration (Teigland & Wasko, 2003; Tushman & Katz, 1980).

Accordingly, I propose the following hypothesis below:

Hypothesis 1a: Institutional prestige will be positively associated with the proportion of external ties.

While more prestigious institutions offer more opportunities and resources for their members to interact with external ties, scholars with varying levels of past productivity may differ in their motivation and ability to leverage these resources to form external ties. First, productive scholars are likely to be more motivated to utilize the across-boundary exchange opportunities available in a prestigious institution to form high proportion of external ties. Individuals are heterogeneous in their capability to perform given tasks. Individuals who are more competent are apt to achieve higher productivity owing to their superior capability. Because the opportunity cost they incur for any collaboration is higher than that of less productive scholars, more productive scholars are more motivated to leverage available resources to form ties with greater returns (Lee, 2010). As previously highlighted, to the extent that non-redundant or novel knowledge are critical for knowledge creation, external ties that provide access to such knowledge would generate higher return, compared with internal ties. Then, relative to their less productive counterparts, more productive scholars will be more motivated to exploit the resources afforded by the prestige of their institution to form higher proportion of external ties, given the opportunity cost of collaboration.

Second, a person with higher prior performance is better able to leverage the reputational effects of institutional prestige by affirming his/her quality as a researcher. I have argued that scholars from prestigious university are likely to enjoy reputational gain – they are usually regarded as high-performing actors. However, in tie formation contexts, there is still great uncertainty over

capabilities and reliability of new partners (Shipilov, Rowley, & Aharonson, 2006). One's prior productivity provides a critical source of track records in such cases. In fact, research has found that individuals consider their potential partner's past performance when making tie formation decisions (Baum, Rowley, Shipilov, & You-Ta, 2005). A good productivity record that signals the superiority in underlying capability, may serve as a solid prove of the reputation afforded by prestigious institution, therefore increasing one's attractiveness to potential external collaborators.

If more productive scholars are more agentic given their higher motivation and ability, then I expect more productive scholars to better leverage the resources afforded by the prestige of their institution to form external ties. Thus, I propose the following:

Hypothesis 1b: Institutional prestige will interact with prior productivity of academic scholars to affect their proportion of external ties such that the positive relationship between institutional prestige and the proportion of external ties will be stronger for more productive scholars.

Internal Network Density

The density of an individual's internal network indicates the extent to which his/her internal partners are directly connected to each other (Sparrowe, Liden, Wayne, & Kraimer, 2001). The internal network density is high when one's internal partners are connected. On the contrary, a sparse social network

occurs when a focal individual bridges otherwise disconnected people who are from the same institution.

In addition to the reputation effect and across-boundary exchange opportunities I have argued previously, prestigious institutions are also likely to house abundant internal resources. Academic institutions are social organizations that offer opportunities for scholars to partake in intellectual discussions and collaborations; and secure collegial recognition and honor for their efforts as they seek to advance knowledge in their academic discipline. Since more prestigious institutions are likely to provide greater instrumental resources such as information, knowledge, opportunities and tokens of recognition as well as economic resources such as research funding and research assistants, members who actively position themselves to be at the nexus of information and knowledge flows – to “be in the know” – can better acquire and appropriate these resources.

Accordingly, I expect members from more prestigious institutions to form *efficient* social connections within their institutions in order to benefit from the economic and instrumental resources available at these institutions. Under social brokerage theory (Burt, 1992; Burt, 2004), sparse social networks or “structural holes” facilitate efficient access to more and diverse information since the absence of ties among one’s contacts implies receipt of non-redundant information. By connecting to people who are not connected, one is exposed to pools of information that circulate within different circles.

One may argue that individuals may not always be aware of who collaborates with whom in the network. Indeed, Friedkin (1983) found that persons who are more than two steps removed from each other in a network are unlikely to be aware of each other's current work. This notion of "restricted horizon of observability" may be true for one's external network where the amount of information one exchanges with his or her collaborators is limited due to the spatial distance and communication inconvenience (Bondonio, 1998). In contrast, individuals are more likely to be accurate in perceiving their internal networks since it is easier for individuals to have frequent face-to-face interaction and get to know colleagues' current work in their physical proximity (Monge, Rothman, Eisenberg, Miller, & Kirste, 1985). Thus, in order to appropriate the rich flows of information and knowledge within a prestigious institution, I argue that its members would invest in non-redundant collaborative ties with their colleagues. Because a sparse collaborative network within one's institution spreads one's ties across unconnected colleagues, I expect members who invest in such networks in prestigious institution to enjoy early access to more new ideas, to participate in more research opportunities, and be aware of career-enhancing prospects such as invited lectures, nominations to editorial positions and so on.

In contrast, where instrumental and economic resources are scarcer – as in the case of a less prestigious institution, affective resources in the form of trust and social support become valuable to develop. The higher levels of help-giving, reciprocity and emotional support associated with denser social

networks (Coleman, 1988) can be enabling to one's career success, to the extent that they provide psychosocial assistance such as confirmation, counseling and friendship that can enhance one's sense of competence and effectiveness (Kram, 1996). While affective resources can hardly be seen as a substitute to instrumental and economic resources in achieving career success; where the latter are less available, the former can be developed to facilitate one's career goals.

Accordingly, I propose the following hypothesis:

Hypothesis 2a: Institutional prestige will be negatively associated with internal network density.

If more productive scholars are more agentic in their social choices given their higher motivation and ability, I expect the pattern between institutional prestige and internal network density would be stronger for scholars who are higher in past productivity. It is argued that more productive scholars will likely choose to form ties with greater returns given the opportunity cost of collaboration. For members from more prestigious institutions, a sparse internal network yields higher returns by providing efficient access to non-redundant information within their institutions. Therefore, compared with their counterparts who are lower in past productivity, more productive scholars will be more motivated to cultivate sparser networks in prestigious institutions.

In addition, due to the signaling effect, scholars with good performance records are likely to be regarded as high-quality actors, thereby enhancing the

likelihood of them being chosen as a tie and also their ties being reciprocated. In this sense, more productive scholars can exercise more selection power over potential collaborators (Zaheer & Soda, 2009). To best leverage the resources available in their institutions, the selection power of more productive actors suggests that they can choose to form ties with greater returns, such as sparse network ties that provide efficient access to non-redundant ideas within a prestigious institution. If more productive scholars are more apt to form sparse networks in prestigious institutions, then I expect the negative relationship between institutional prestige and internal network density to be stronger for more productive scholars compared with their less productive counterparts.

Therefore, I propose the following:

Hypothesis 2b: Institutional prestige will interact with prior productivity of academic scholars to affect their internal network density such that the negative relationship between institutional prestige and internal network density will be stronger for more productive scholars.

METHODS

Sample and Data

I tested my hypotheses using data on a random sample of academic scholars in the Management discipline. To draw the sample, I first searched for

articles published during a 20-year time frame (1986-2005), under “Management” and “Business” categories in ISI Web of Science. This search yielded 79900 articles and 58,508 authors. Among these authors, about 78% of them published only one or two articles categorized under the Management and Business field across the 20 years. As I am interested in research-active scholars in the Management discipline, I focused on the remaining 22% of scholars who published at least three articles in this 20-year period, reducing the population to 12,724 authors.

I then used proportional-stratified random sampling to draw my sample from this population. I categorized the population of 12,724 scholars into five sub-groups: (1) scientists with 3 publications comprising 32.5% of the population, (2) scientists with 4 publications comprising 18.4%, (3) scientists with 5 publications comprising 11.6%, (4) scientists with 6-12 publications comprising 28.1%, and (5) scientists with more than 12 publications comprising 9.4%. Figure 1 displays the frequency distribution of this population. Then I randomly selected scientists within each sub-group to approximate the distribution of the population. My final sample comprises of 293 academic scientists, of whom 32.1% published 3 articles, 19.1% published 4 articles, 12.0% published 5 articles, 26.3% published 6-12 articles, and 10.6% published more than 12 articles. The cumulative frequency of the sample approximates the distribution pattern of the population, as shown in Figure 1 with the dashed line indicating my sample’s cumulative percentage and the solid line indicating the population’s cumulative percentage. I also conducted a power analysis

(Cohen & Cohen, 1983). In order to achieve a power level of 0.80 and a medium effect size ($f^2 = 0.15$), a sample size of at least 108 individuals is required. Hence, my final sample of 293 scholars would be sufficient for my analysis. Where there is missing data of a scholar such as curriculum vitae, I would randomly select another replacement.

Insert Figure 1 about here

Data were mainly obtained from two sources. First, information regarding each scholar's career movements and academic activities were obtained primarily from their biographies, which include education history, position held and institutional affiliation, awards, editorial positions etc. I downloaded their biographies from the scholars' personal or institution's website, and coded each scholar's institutional affiliations, including their doctorate program and their subsequent appointment as assistant professor, and the year of the job movement. When the institutional affiliation information was incomplete in the personal biography, I searched for articles the scholar published during the period near the career transition in order to identify his or her institutional affiliation during that period.

Second, I constructed each scholar's collaborative network by using their co-authorship publication records, extracted from Scopus database. Scopus is currently the largest abstract and citation database of peer-reviewed literature, which is continually expanded and updated. As described by the owner, Scopus

contains 55 million records, collected from over 35,000 peer-reviewed journals. Compared with ISI Web of Science, Scopus offers wider coverage, in terms of the number of indexed publications (Bar-Ilan, 2008; Vieira & Gomes, 2009). One potential problem of using publication or patent data is that some individuals use different spellings in their publication or patent record, and several authors have similar names (Azoulay, Ding, & Stuart, 2009; Newman, 2008). Scopus author identifier helps to differentiate authors with similar names and group together name variants of a same author (see Appendix for details). Another advantage of Scopus is that it contains academics' profiles that include their institutional affiliations as well as subject areas of interest. Whenever the search returned more than one authors under a same name, I refer to the affiliation or subject areas, and crosschecked the information available in Scopus profiles with what I obtained from their curriculum vitae to ensure that I selected the appropriate name for my search. I downloaded the publication records for each scholar in my sample. Year of publication and every co-author's name were then coded for each publication. I also coded the institutional affiliations of the co-authors based on the information printed in journal articles.

Since I am interested to examine how academic scholars in their early careers cultivate collaborative networks that "fit" the academic prestige of their institution, I identified the year in which a focal scholar was appointed as assistant professor as the transition year (year t). Consistent with prior research on social networks (e.g. (Cattani & Ferriani, 2008; Fleming et al., 2007), I used

a three-year window – beginning from the transition year t – to reconstruct the post-transition collaborative network of each scholar [i.e., t to $(t+2)$], and the three-year window prior to the transition year to reconstruct the pre-transition collaborative network [i.e., $(t-3)$ to $(t-1)$]. Scholars are likely to move from one institution to another. The average tenure in the first position in my sample is 4.68 years. Thus I chose a relatively shorter time period to capture their mobility moves. To check the robustness of my results of windows of a different length, I conducted the same analyses using four-year windows to aggregate network measures, and the pattern of results remained largely the same. I reported the results based on 3-year window because the 3-year window provided better fit.

Measures

Proportion of External Ties. Proportion of external ties was computed as the ratio of the number of external ties to the number of total ties. I use ratio instead of pure count of external ties because ratio reflects the relative time and attention one allocates to investing in external ties.

Internal Network Density. Internal network density was measured as a ratio of the unique number of pairwise collaborations between an scholar's internal co-authors excluding the focal scholar to the total possible pairwise collaborations between the internal co-authors in a three-year window (Fleming et al., 2007; Obstfeld, 2005; Podolny & Stuart, 1995). This measure ranges from 0 to 1, where a lower score indicates that a scholar has a sparser internal network.

Institutional Prestige. Prestige of a scholar's institutional affiliation at the year of transition t (*Institutional prestige*) was measured using the *Gourman Report* (Gourman, 1997). The *Gourman Report* has been used in prior research as a measure of the prestige of academic institutions (e.g., (Judge, Cable, Colbert, & Rynes, 2007; Rindova, Williamson, Petkova, & Sever, 2005; Williamson & Cable, 2003), and it is considered as the only guide to the prestige of higher education program that assigns numerical ratings (ranging from 1.0-5.0) to virtually every degree-granting university in the United States (Cable & Murray, 1999). I coded the prestige of a scholar's institution at the year of transition t (i.e., at assistant professor appointment).

Past Productivity. Following McFadyen and Cannella (2004), I used impact-factor-weighted publications to assess scholars' productivity. Specifically, the count of journal articles is weighted by the impact factor of the journal in which a particular article appears in a given year. I then aggregate a scholar's impact-factor-weighted count of journal publications prior to the transition year. For example, if a scholar publishes 1 paper in Journal A, the impact factor of which in the year is 5, and 3 paper in Journal B, the impact factor of which in the year is 2, then the scholar's impact-factor-weighted count in the year is $5 \times 1 + 2 \times 3 = 11$. The assumption underlying this measure is that articles published in a journal of higher impact are of higher importance or quality. The yearly journal impact factor scores are obtained from the *Journal Citation Reports* (JCR) of the ISI. The ISI adjusts the measure to remove the advantage of larger journals over smaller, of frequently issued journals over

less frequently issued, and of older journals over newer (McFadyen & Cannella, 2004). However, the JCR is only available in the ISI beginning from 1999. For those earlier years (i.e., before 1999), I use the *mean* impact factor scores, i.e., the average impact factor score across 15 year from 1999 to 2013. I also tested an alternative measure using the impact factor scores in 1999 to replace the mean for the years before 1999, and the results were not significantly different.

Other Controls.

I included several additional control variables. First, I controlled for a scholar's *Gender*, with 0 designating female and 1 designating male (Fox, 2006). Second, because one's doctoral origin is likely to affect his or her subsequent career and collaborations especially in the early career stage (Long et al., 1979), I controlled for scholars' *Doctoral Prestige* using the ratings from Gourman Report (Gourman, 1997).

Third, tokens of honor such as research or publication-related awards are likely to affect academics' visibility in the discipline and, thus, their success at forming collaborative ties. Therefore, I included a dummy variable (*Research Awards*), taking value 1 if a given scholar received a research award, zero otherwise. Fourth, academic journals' editorial boards may represent important sources for new collaborations. Hence, I controlled for *Editorial Position* as a dummy variable, with 1 indicating that a focal scholar was found involved in an academic journal's editorial board (including editor, assistant/associate editor, editorial board member), zero otherwise. Fifth, I controlled for the size of scholars' prior networks (*Network Size*), because the number of collaborators

they previously had can affect their opportunities to form subsequent collaborations. This measure counts the total number of co-authors whom a scholar had collaborated with in the three-year window prior to the focal assistant professor appointment under examination.

Finally, the relationships between institutional prestige and post-transition network characteristics are likely to be confounded by their common dependence on a third latent variable – the pre-transition network status. For example, individuals who were connected with a lot of external ties are more likely to be hired by prestigious school, and also tend to have higher proportion of external ties in their post-transition networks. Hence, I included the number of pre-transition external network ties when testing the relationship between institutional prestige and the post-transition proportion of external ties. For a similar reason, I controlled for pre-transition internal network density when investigating the effect of institutional prestige on post-transition internal network density.

Statistical Methods

My dataset contains 293 scholars from 131 institutions. These data is multilevel in nature, with the individuals nested within clusters (i.e., institutions). Since my data includes repeated observations within institutions, fixed effects models, which assumes that all observations are independent of each other, are not appropriate in this case (Hedeker, 2005). Instead, I applied generalized mixed linear model regression to take into account the autocorrelations within the data (Jennrich & Schluchter, 1986; Liang & Zeger,

1986). A mixed model includes the usual fixed effects for the regressors plus the random effects. By adding the random effects, mixed models account for the fact that clustered observations are similar by estimating the variance among cluster means and among observations within a cluster. It basically partitions the variance in the outcome variable into cluster-level and observation-level parts. In addition, this technique allows one to specify covariance structures and fit those structures using a restricted (or residual) maximum likelihood method.

To implement the mixed models, I specified a Gaussian distribution with an identity link function and the exchangeable correlation as the covariance structure. I also fitted models specifying other types of covariance structures, including independent, identity, and unstructured correlations within institutions. Significance findings for hypothesis testing were the same with each approach. The findings for the exchangeable correlations model are reported here since that model yielded the best fit to my data.

RESULTS

Table 1 presents the descriptive statistics and a correlation matrix for the variables used in the analyses. As a check for multicollinearity, variance inflation factor (VIF) scores were calculated for the variables in each regression model. All VIF scores were well within the limit of 10, indicating that multicollinearity did not have an undue influence on the estimates. Furthermore, as several authors have recommended, I entered mean-centered

independent variables before creating the interaction term to minimize potential multicollinearity problems (e.g., (Cronbach, 1987). I ran hierarchical regressions to test the hypotheses.

Insert Table 1 About Here

Table 2 presents the results for how institutional prestige affects the proportion of external ties one forms in the subsequent three-year time window. I tested the relationship between prestige of current institutional affiliation and the proportion of external ties in the post-transition collaborative network, controlling the effect of the number of pre-transition external network ties and other control variables. Hypothesis 1a argued that the more prestigious the institution the larger proportion of external ties scholars will have in their collaborative networks. Model 2 in Table 2 shows that institutional prestige was indeed a significant predictor of the proportion of external ties ($\beta = 0.10, p < 0.05$). Thus, Hypothesis 1a was supported. In Model 3, I tested the interaction terms of institutional prestige with past productivity in the regression model. Contrary to expectation, past productivity did not moderate the relationship between institutional prestige and the proportion of external ties ($\beta = 0.01, p > 0.10$). Hypothesis 1b was not supported.

I also assessed the relationship between prestige of current institutional affiliation and post-transition internal network density, controlling for pre-transition internal network density and other control variables. The regression

results are reported in Table 3. As shown in Model 5, the coefficient of current prestige was negative and significant ($\beta = -0.04, p < 0.05$), which is in line with my arguments that a scholar who is affiliated with a more prestigious institution is more likely to have a sparse internal collaborative network. Thus, Hypothesis 2a was supported. In Model 6, I found significant moderation effect of a scholar's past productivity on the relationship occurring between institutional prestige and internal network density ($\beta = 0.02, p < 0.05$). However, the moderating impact is opposite to the hypothesized effect. As demonstrated in Figure 2, the negative relationship between institutional prestige and internal network density was stronger for less productive scholars. Thus, Hypothesis 2b was not supported.

 Insert Tables 2 and 3 about here

 Insert Figure 2 about here

Robustness Checks

I tested the sensitivity of the results in several ways. First, since the sample size of my dataset is relatively small, I collected another random sample of 281 scholars to test the robustness of my findings. I used the same analysis

approach to examine this second dataset, and the results were consistent with what I found with the first dataset. Second, in academia, scholars often collaborate with their doctorate advisor – especially in their early career stage – and their PhD student. I excluded this particular type of collaborations with doctoral mentors and direct students, and ran the regressions again.¹ The results were qualitatively the same.

Third, the proportion of external ties and internal network density will only be observed on individuals who have at least one collaborator. At the same time, a scholar's propensity to collaborate widely is also likely to be correlated with one's being hired by prestigious institution. Hence, to correct for possible sample selection bias, I estimated a first-stage selection model (Heckman, 1979) for all scholars and entered the inverse Mill's ratio in the second stage. The ratio essentially controls for an individual's propensity to collaborate widely. Specifically, I first obtained an inverse Mills ratio from a probit regression, with the dependent variable taking 1 if the scholar collaborates with at least one other coauthor and 0 otherwise. The first stage used variables that would correlate with a scholar's number of collaborators, including citations counts, number of publication, and tenure in the field. I then included in the inverse Mill's ratio as an additional variable in the regression models. The results held in this robustness check.

¹ The scholar's doctorate mentor was extracted from their PhD thesis, and the names of their direct students were obtained from their Curriculum Vitae.

DISCUSSION

By drawing from both the structural and agentic perspectives, I sought to examine how institutional prestige and individual productivity influence academic scholars' collaborative social networks in their early careers. Focusing on a sample of academic scholars in Management field, I found that structural conditions and individual human capital factors both matter in forming collaborative networks. On the one hand, the significant associations between institutional prestige and scholars' subsequent collaborative networks provide support for the structural view that institutions provide opportunities or constraints for their members to form certain ties. I found that, controlling for the prestige of the institution where scholars were previously affiliated, the higher the prestige of the institution where the scholars secured their employment, the more attention they will allocate to forming external ties and the sparser the internal network they will have. On the other hand, I also found evidence that individual productivity moderates the effects of institutional prestige on scholars' collaborative networks, in particular with regard to their internal network structure. Contrary to my expectation, relative to their more productive counterparts, less productive scholars are actually more motivated to actively appropriate the non-redundant knowledge within prestigious institutions by cultivating sparse internal networks.

My study contributes to the social network literature in several ways. First, I add to the structural perspective of social network formation by showing that

academic scholars exhibit collaborative networks that co-vary with institutional prestige as the level of resources available at their institution are likely to differ. I observed that academics affiliated with more prestigious institutions in their assistant professorship appointment allocated more of their time and attention to the development of external ties, compared with those from less prestigious institutions. This implies that prestigious institutions can provide more opportunities and economic support for their members to reach out for external ties that are often associated with more non-redundant information. Besides, a prestigious institution is also likely to house ample internal resources, including more intellectual, economic resources and opportunities to participate in research projects. Hence, its members cultivated sparser collaborative ties, or a more expansive network within the institution to appropriate the rich flows of information and resources internally. Comparatively, in less prestigious institutions where opportunities and supports are scarcer, scholars have to spend additional time and effort to develop and maintain external collaborations. When the cost of forming external ties outweighs its benefit, scholars will invest less in developing external ties. Internally they maintained denser collaborative ties in their institution as affective resources such as trust and social support become valuable to build when economic or instrumental resources become less available.

Second, while acknowledging the significant influence of social conditions on individuals' social networks, I incorporate the agentic perspective by highlighting that individuals can be active agents in orchestrating their social

networks within the structural setting. Despite the social structural opportunity (or constraint) posed by their institutions, academic scholars differ in their motivation to actively leverage the resources afforded by their institutions. In particular, I found that individual productivity plays a moderating role in how institutional prestige affects scholars' internal network structure. But contrary to my hypothesis, the negative relationship between institutional prestige and internal network density was stronger for less productive scholars. It appeared that compared with their peers who are higher in past productivity, less productive scholars are more motivated to develop sparser networks in prestigious institutions. It is plausible that less productive scholars in prestigious institutions have greater pressure to publish, due to the more competitive peer environment and higher performance standards at more prestigious institutions, and thus are more motivated to cultivate sparser networks to acquire non-redundant information for knowledge creation. This finding suggests that while prestigious institutions offer more economic and instrumental resources, scholars may not be equally agentic in forming efficient network ties to appropriate these resources.

With regard to the moderating effect in external networks, I found that past productivity did not moderate the significant relationship between institutional prestige and the proportion of external ties. I had argued that more productive scholars are likely to be motivated to exploit the resources offered by the prestigious institution to form higher proportion of external ties, given the opportunity cost of collaboration. In addition, a superior productivity record is

likely to add to one's attractiveness to his/her potential external collaborators. However, less productive scholars in prestigious institution are likely to be equally motivated to form high proportion of external ties, because they are under greater pressure to enhance their performance, due to greater peer pressure and higher performance standards at prestigious institutions. Furthermore, to the potential collaborators outside of a focal scholar's institution, the institutional reputation serves as a stronger or more direct signal of one's underlying capability, than the past productivity of an individual. Without getting to know one's past productivity, being affiliated with a prestigious institution alone would be considered as an indicator of research ability. This suggests that scholars from a prestigious institution are likely to have higher proportion of external ties mainly because they enjoy more opportunities and reputational benefits from their home institution to interact with potential external partners. Considering this together with the significant moderating effect of prior productivity I found for the internal network, it appeared that while opportunities afforded by the structural condition seem to be the major predictor of one's external network, individuals are likely to exercise more agency in forming their internal networks.

Limitations and Suggestions for Future Research

There are some potential limitations to this study. First, the definition of internal and external ties may not be very clearcut in cases that involve new hires. For instance, a tie with a new hire in an institution will be considered as an internal tie, but this hire is likely to non-redundant information. Similarly, a

tie with an external faculty who just left the same institution may have high information redundancy. However, this may not pose such a big risk in my current analyses. It often takes a few years from initiating a collaborative project to finally getting it published. For example, the internal partner was a new hire who just moved to the focal scholar's institution at the beginning of the project. In the following years, as the project progressed, the internal partner was likely to possess increasing redundant information as he/she got socialized in the institution and participated in the knowledge exchange activities with colleagues. In the situation where a tie with external partner who just left the same institution, the partner may have high information redundancy in the beginning. But since the partner was already in a different institution, he/she was exposed to a different academic environment, and may therefore bring in non-redundant information into their collaborative research subsequently. Hence, the argument of internal ties involving redundant information while external ties providing non-redundant information may still apply in such circumstance. To account for the possibility that the effects of institutional prestige on a scholar's collaborative networks may be lagged, I conducted a sensitivity analysis using DVs at time window from $(t+1)$ to $(t+3)$, where t represents the transition year. This is to ensure that the focal scholar had been in the institution for at least one year. After spending one year in the current institution, the tie with a former colleague will be more qualified as an external tie, as he/she will have more non-redundant knowledge from the focal scholar, while the tie with a current colleague will be more qualified as an internal tie,

who possess increasing knowledge redundancy. The pattern of the results, using DVs at (t+1, t+3), remained similar. I also ran the same analyses using DVs at (t+2, t+4). Although the effects of institutional prestige become marginally significant, the directions of the effects were consistent. Further, to more clearly distinguish internal and external ties, another potential solution might be to collect additional data on the coauthors' tenure in a particular institution. For example, I can define a tie as "internal" only after the new hire has been in the institution for at least 1 year. Similarly, a tie is defined as "external" only if the new hire has been in the institution for 1 year. Then I can test if the recoding of the data will change the results.

Second, as my study reconstructed academics' collaborative network from their publications, I am unable to capture collaborative ties that did not result in publications. Consequently, there is a risk that the collaborative ties are under-represented in my sample. Nonetheless, the risk of under-representation of collaborative ties applies to all the scholars in my sample; I know of no reason that scholars in more prestigious institutions may experience a higher or lower risk of such under-representation than those in less prestigious institutions. If the risk is randomly distributed across the sample, then the associational relationship between institutional prestige and collaborative network is unlikely to be systematically biased.

Third, in examining the relationship between institutional prestige and collaborative networks, I focused on academics' prestige at their first assistant professor appointment and their subsequent collaborative network because this

was a career stage where academics are likely to rely more on their institutional prestige and be keen to proactively form collaborative ties. However, I am conservative to generalize the results to one's whole career, since the pattern of relationships between institutional prestige and collaborative networks may not remain the same when academics have a more established academic reputation or have been awarded tenure. Future studies can incorporate a longer time frame to investigate the potential moderating effect of career stage.

Practical Implications

My study has practical implications for research organizations and scholars. First, my findings show that individuals from more prestigious institutions are likely to form higher proportion of external ties. This suggests that institutions provide opportunities or constraints for their members to form certain network composition, in particular with regard to the proportion of external ties. Given that external ties are beneficial to knowledge creation as they are likely to introduce non-redundant information and ideas, organizations should provide more across-boundary exchange opportunities and supports for their members to form external ties, and create an environment that will attract external scholars. Second, my results reveal that people who are lower in past productivity are more motivated to acquire the resources available within prestigious institutions by cultivating sparser internal networks. I highlight that while prestigious institutions offer more economic and instrumental resources, scholars may not equally leverage these benefits. To maximize their access to

the advantages afforded by their organizations, individuals can exercise more agency by more actively forming efficient internal networks according to their personal status.

CHAPTER 3

Internal Knowledge Structure and Collaborative Tie Formation: Integrating Cognitive and Social Network Perspectives

INTRODUCTION

Knowledge is a major creative force of knowledge professionals. Individuals' ability to create innovations is influenced by the extent to which individuals can effectively and efficiently search for, access, transfer, assimilate and apply knowledge (Galunic & Rodan, 1998; Nahapiet & Ghoshal, 1998). Central to the investigation of knowledge creation is the role of interpersonal collaborative networks. A large and growing body of empirical research has showed that different features of social relationships and the networks they constitute affect the efficacy and efficiency of knowledge exchange and creation (e.g., (Burt, 2004; Hansen, 1999; McFadyen & Cannella, 2004; Reagans & McEvily, 2003). For example, focusing on the structural dimensions of networks, some scholars found that structural holes enhance individual knowledge creation (e.g., (Burt, 2004; McFadyen et al., 2009), while other scholars found that network closure promotes the adoption of an inventor's novel idea (Fleming et al., 2007). Taking a relational perspective of networks, studies have shown that weak ties had a positive effect on creativity (Perry-

Smith, 2006; Perry-Smith & Shalley, 2003), while strong interpersonal ties are more effective in enhancing knowledge transfer and learning (e.g., (Bouty, 2000; Levin & Cross, 2004; Uzzi & Lancaster, 2003).

However, the common presumption of this stream of work that networks affect knowledge outcomes may be challenged by a reverse causality. For instance, scholars have demonstrated that individuals who are well connected to others in the network exhibit superior performance, because centrality provides individuals with timelier access to more diverse information, increasing their potential to create new knowledge (Burt, 2004; Morrison, 2002). Yet this unidirectional causality can be challenged by the possibility that better-performing persons are more attractive as potential partners and therefore come to occupy a more central network positions (Lee, 2010). This suggests that the relationships between social networks and knowledge outcomes may not be unidirectional.

Compared to the knowledge outcomes of social networks, I know little about how individuals' existing knowledge influences network formation. Knowledge stock reflects the amount of knowledge elements that one has accumulated over time. It is plausible that individual differences in the breadth and depth of internal knowledge can not only influence their ability to acquire new knowledge, but also directly affect the likelihood of successfully forming a collaborative tie. This happens if actors with substantial knowledge stock are more attractive as collaborators, and more importantly if they can overcome the communication obstacles and more efficiently exchange knowledge with

potential partners. Prior research provides circumstantial support for this phenomenon. Firstly, individuals form beliefs about the quality of others based on revealed performance (Lee, 2010). For potential collaborators, one's knowledge stock provides a critical source of track records. Scholars with substantial knowledge stock are likely to be regarded as higher-quality actors, and hence receive more collaboration invitations. Secondly, from an absorptive capacity standpoint, individuals or organizations can use existing knowledge to recognize and assimilate new knowledge from their network contacts (e.g., (Cohen & Levinthal, 1994). Other studies suggested that productive collaborations require some level of overlapping knowledge among exchange partners (Grant, 1996). For instance, an individual must have substantial basic knowledge – knowledge that overlaps that of exchange counterpart – to be an effective partner in a scientific experiment (Polanyi, 1966). In addition, actors with diverse and deep knowledge often have higher capacity to transfer knowledge to others; that is, they are better able to convey ideas and concepts in a way that a contact can understand, thus fostering the efficiency of knowledge transfer (Salomon & Martin, 2008).

Thus, individuals' knowledge stock not only serves as a signal of their research competency, but also reflects their ability to absorb new information and effectively transfer knowledge to others. Especially when the focal individual (ego) does not have any collaborative experience with a contact, such ability will ease the communication and knowledge exchange, and enhance the likelihood of an initial casual encounter to become a fruitful collaboration

subsequently. Therefore, substantial knowledge stock can lead to advantages in forming new collaborative ties. Specifically, as summarized in Figure 3, I expect that the actor-level heterogeneity in the structure of knowledge stock can predict the number of new knowledge components one acquires, and also the number of new ties he/she forms, and that new ties will partially mediate the relationships between existing knowledge structure and the number of new knowledge components that are acquired subsequently.

Insert Figure 3 about here

I test my theory on the collaboration network of academic scholars in the field of Psychology. Goals and work of academia revolves around the integration and creation of knowledge. Scholarly publications are the main knowledge production of academic scholars, which provide a good source to study their knowledge profiles. In addition, academic scholars frequently collaborate with others to integrate their knowledge in the pursuit of new knowledge creation (Moody, 2004). Relative to other organizational settings, academic scholars enjoy considerable leeway in deciding on their collaborative partners in their research. These characteristics of the academic community establish an ideal setting for my study of how individuals' internal knowledge structures affect the formation of new ties.

THEORY AND HYPOTHESES

Two Sides of New Collaborative Ties

Classic works have theorized two broad forces that influence changes in social network ties (Ahuja et al., 2012; Zaheer & Soda, 2009). The first is structural enablers and constraints that induce opportunities, social norms or habits that determine how actors behave toward their social network relations (e.g., (Kossinets & Watts, 2009; Zaheer & Soda, 2009). Structure, in this perspective, cover a wide theoretical terrain including not only existing social network structure but also organized social setting that influence social interactions. The second is human agency, emphasizing the focal actor's motivation and ability to shape relations. In this view, actors deliberately seek to create a beneficial link or dissolve an unprofitable one according to their homophilous (McPherson et al., 2001; Reagans, 2011) or heterophilous preferences (Moody, 2004; Rivera et al., 2010).

From an agentic perspective, I argue that people are motivated to form new ties – subject to their ability to overcome the uncertainties in knowledge exchange – because new ties provide access to novel information that is critical to knowledge creation, but the amount of new ties one can actually establish depend on individual ability. Creativity and innovation require sufficient knowledge variety for potential recombination of different ideas. Although exposure to new ideas and elements can be increased in various ways, such as through education and reading, much, and possibly most exposure occurs

through social interactions with others (Allen, 1977; Katz & Lazarsfeld, 1955). New ties, in particular, are believed to foster knowledge variety by functioning as pipes that carry different and diverse information due to the lack of shared history and experience. Knowledge exchanges in the course of collaboration can homogenize task knowledge as well as problem solving approaches among collaborators to some degree (Uzzi & Spiro, 2005). Hence, individuals who collaborate repeatedly may have great knowledge overlap, while new ties, characterized by very short history of interaction and lack of shared experience, are unlikely to have the risk of homogenization of common knowledge; instead, new ties are more likely to be dissimilar to the ego and, thus, are more likely to expose ego to dissimilar information and perspectives.

Yet, the benefit of information novelty associated with new ties comes with liability to knowledge exchange. It is easier for knowledge to transfer from the source to a recipient when the source and the recipient have knowledge in common (Reagans & McEvily, 2003). Shared knowledge is often developed and increased in the course of collaboration when problem-solving discussions transfer task knowledge between collaborators. Relative to repeated collaborations, new ties lack shared knowledge that fosters sharing. In addition, without any prior collaborative experiences, new collaborations often lack common routines to work together, which also creates obstacles for efficient communication and problem solving. Therefore, new collaborators are disadvantaged in their familiarity with each other's knowledge, perspectives and working styles, thus creating challenges in communicating complex ideas

and combining their knowledge. The lack of shared cognitive and normative understanding is likely to frustrate attempts to form new ties. To overcome knowledge exchange barriers, individual effort and motivation for novel information are important factors, but individuals' existing knowledge, which can be translated into abilities to absorb new information from and effectively transfer knowledge to any potential collaborators, also plays a role. The influence of knowledge structures is addressed in the following section.

Individual Knowledge Stock

Knowledge stock reflects the amount of knowledge elements that one has accumulated over time (Dierickx & Cool, 1989). To examine the influence of knowledge stock on knowledge acquisition and tie formation, I specifically focused on two key dimensions of individual knowledge stock – breadth and depth. Prior studies tend to conceptualize knowledge breadth and depth as two extremes of the same dimension, because of the trade-offs required in devoting the time to develop either specialized knowledge areas, or a wide range of knowledge domains (Kim, 1989; Schilling, Vidal, Ployhart, & Marangoni, 2003). Recent research appears to recognize that breadth and depth are two distinct dimensions of knowledge rather than two ends of one continuum. At the organizational level, Katila and Ahuja (2002) defined the breadth and depth of a firm's knowledge as the scope (local versus distant) of the firm's search efforts and the degree to which existing knowledge is exploited or reused respectively. This conceptualization suggests that organizations can pursue breadth and depth of knowledge at the same time. This idea is also consistent

with the finding that organizations often have loosely coupled and differentiated subunits or individuals, each of which specializes in either knowledge search and exploration or knowledge reuse and exploitation (Gupta, Smith, & Shalley, 2006). At the individual level, in their study on inventor expertise, Boh, Evaristo and Ouderkirk (2014) also treated breadth and depth as two separate dimensions. They found that a group of polymath inventors display both high breadth and high depth of expertise. These inventors usually have deep knowledge in one or a few core technical domain areas, and some knowledge of many technical domain areas. These suggest that knowledge stocks vary in breadth and depth, for organizations and individuals.

In academia, it is not hard to find scholars who are specialists in their core expertise areas and also spanning across multiple domain areas. Hence, consistent with the recent stream of research, I consider breadth and depth as two distinct dimensions of a knowledge base that reveal both the structure and content of the knowledge one holds (Zhou & Li, 2012). Specifically, knowledge breadth refers to the extent to which an individual's knowledge stock contains distinct and multiple domains; knowledge depth refers to the level of sophistication and complexity of knowledge in one's core knowledge domains (Bierly & Chakrabarti, 1996). The breadth attribute reflects the horizontal dimension of knowledge and heterogeneity of knowledge content, whereas the depth attribute captures a vertical dimension and unique, complex, within-field knowledge content (De Luca & Atuahene-Gima, 2007).

In this study, I examine how individuals' knowledge stock influences their

knowledge acquisition and tie formation. Acquisition of new knowledge is essential for knowledge workers to producing creative outcomes. Creativity and innovation require sufficient knowledge variety for potential recombination of different ideas. Variety, in turn, is associated with knowledge acquisition, involving searching for, discovering, creating, and experimenting with new knowledge and opportunities. Under the pressure to publish, scholars in academia are motivated to broaden their existing knowledge stock and improve the knowledge-recombinant opportunities. Yet an individual's scope and capacity to comprehend and apply novel knowledge are delimited by one's existing knowledge. Research in the area of cognitive and behavioral sciences suggests that people need prior knowledge to assimilate and use new knowledge. Knowledge stock also impacts individuals' formation of new ties. Actors with substantial knowledge stock are not only more attractive to their potential partners, but also more effective in knowledge exchange due to higher knowledge absorptive and transfer capacity, which enhances the likelihood of an initial encounter to become a successful collaboration.

The Influence of Knowledge Breadth on Knowledge Acquisition and Tie Formation

Breadth in knowledge is beneficial for knowledge acquisition. Research in individual cognitive sciences suggests that one of the most important ways that people learn new ideas is by associating those ideas with what they already know (Bower & Hilgard, 1981). An individual's knowledge base consists of a set of concepts, and these concepts can be relatively easily used as a foundation

for the acquisition of new concepts that is related to the pre-existing knowledge. This process allows reuse of things already learned and also provides a basis to which new items of knowledge can connect, thereby lowering the cost of learning. In this regard, breadth in knowledge increases the prospect that incoming information will relate to what is already known, hence enhancing the effectiveness of knowledge acquisition (Cohen & Levinthal, 1990).

Breadth in knowledge will also foster tie formation. Scholars with broad knowledge base are likely to publish across different domains. They may therefore have more opportunities to form new collaborative ties as they are more visible to potential collaborators from diverse backgrounds. More importantly, as discussed previously, people rely on prior related knowledge to assimilate and use new knowledge. As a result, people find it easier to learn new ideas in areas in which they have some experience and find it more difficult to absorb new ideas beyond their immediate area of expertise. An implication is that it is easier for knowledge exchange to happen between two actors who have knowledge in common. Research has found that indeed common knowledge can ease the exchange of knowledge (Reagans & McEvily, 2003). Especially when two persons do not have any prior experience working together, there is uncertainty about the knowledge domains from which potentially useful information may emerge. In such setting, a diverse knowledge base provides a more robust basis for knowledge absorption and transfer because it increases the chance that the focal person will have some initial shared language and knowledge overlap with the new partner to start a

collaboration. In addition, people connected to multiple bodies of knowledge are exposed to more worldviews and more likely to be aware of languages in different areas. Hence, they are not only more open to explore new perspectives, but also better able to evaluate and comprehend the value of local knowledge in more adjacent fields and then frame their communication in a way that the potential partners can understand.

In all, people with diverse and broad knowledge stock have higher capacity to absorb and transfer knowledge. Hence, they are more likely to be able to effectively communicate with a new contact, thus turning an initial encounter into a successful collaboration. Accordingly, I predict that knowledge breadth will positively influence knowledge acquisition and tie formation. More formally, I hypothesize:

Hypothesis 1: Knowledge breadth is positively associated with new knowledge acquisition in the subsequent period.

Hypothesis 2: Knowledge breadth is positively associated with the number of new collaborative ties one forms in the subsequent period.

The Influence of Knowledge Depth on Knowledge Acquisition and Tie Formation

Different from knowledge breadth that concerns the variety of knowledge stock, depth of knowledge is associated with specialist knowledge manifested by mastery of one or a few subjects, which is usually achieved through repeated research and practice. To develop an effective absorptive capacity, depth in

knowledge, or intensity of effort is critical (Cohen & Levinthal, 1990). First, people who have spent more effort in learning a particular subject will find it easier to retrieve the knowledge subsequently. With regard to memory development and storing knowledge, Lindsay and Norman (1977) suggested that the more deeply the material is processed – the more time and effort applied, the more processing makes use of associations between the knowledge items – the better will be the later retrieval of the item. Since people tend to associate incoming information with what they already know in learning new ideas, easier retrieval of prior knowledge would accelerate such association. Second, depth in knowledge allows a scholar to understand the complex causal linkages of the existing components within one's core domain areas (March, 1991), and apply knowledge from a set of familiar elements (the relation of A to B) to relations about yet unknown elements (the relation of C to D) (Sternberg, 1977). With greater knowledge depth, individuals can better apply analogical reasoning and make connections between the pre-existing source knowledge and the new target (Vosniadou, 1989). Third, there may also be a transfer of learning skills across bodies of knowledge. Intensive exposure in one knowledge area may influence and improve learning in another task (Ellis, 1965). Hence, the depth of prior knowledge would promote subsequent acquisition of new knowledge through easier retrieval of expertise and transfer of both domain knowledge (through analogical reasoning) and learning skills.

In the same vein, knowledge depth can facilitate knowledge exchange and communication in developing a new tie. In uncertain situations, scholars with

deep knowledge in their core domain areas will have higher capacity to absorb new information in that they are able to retrieve their expertise more easily, and transfer their knowledge from the existing knowledge set and apply it correctly to a novel knowledge set. Even if the incoming information is not directly related to the prior knowledge stock, one can use his/her core expertise to make sense of the new information through analogical reasoning; the learning skills one has acquired during the development of his/her core expertise may also enhance learning in another domain.

In addition, depth in knowledge enhances one's ability to transfer knowledge to others. Individuals with knowledge depth are better able to convey complex ideas, concepts, and information clearly, accurately and also in an understandable way, to the potential collaborators who could be from a different knowledge background. Furthermore, as the level of knowledge depth increases, a scholar is likely to be perceived by his or her peers as an expert in a particular area and thus attract more potential partners to approach for collaborations.

On the other hand, depth of knowledge also has its downside. I believe that the above-discussed positive relationships apply only to a certain level of knowledge depth beyond which knowledge depth exerts negative impacts on knowledge acquisition and tie formation. The risk of knowledge myopia in the search process is more likely when a scholar's research is highly specialized (Rotolo & Petruzzelli, 2013). When one's knowledge depth reaches a certain level, he or she could be cognitively fixated, and tends to rely upon a limited

variety of knowledge. A scholar searching for knowledge locally may be less inclined to adopt ideas and incorporate ideas from other fields. As a result, one's exploitation of his or her core expertise may evolve into core rigidities – inappropriate knowledge sets that preserve the status quo (Teigland & Wasko, 2003).

In addition, as a scholar's knowledge depth further increases, the difficulties in seeking out knowledge and resources that involve collaborations with other scholars that operates in domains, which are distant from the one of his or her own specialization, also increase due to the higher cognitive distance (Andrews & Delahaye, 2000; Rotolo & Petruzzelli, 2013). There are limits to which analogical reasoning and transferability of learning skills can occur to other bodies of knowledge. Bodies of knowledge are related to one another in different degrees. As knowledge bodies become more distant in space, analogical reasoning and transferability of learning skills to other bodies become increasingly difficult. Hence, a highly specialized scholar, compared with his or her less specialized peers, has to invest more attention and time in the process of exchanging knowledge and communicating with potential partners. According to the perspective of bounded rationality (e.g., (Cyert & March, 1963), a highly specialized scholar may only be able to form limited number of new ties because of higher investments of attention in developing collaborative relationship with each new partner. Thus, as knowledge depth further increases and reaches a certain level, there are not only motivational barriers such as knowledge myopia that reduce inclination to acquire

knowledge or partners in other domains, but also knowledge absorption and transfer barriers that reduce successful new knowledge acquisition and formation of new collaborative ties.

Accordingly, I posit the following hypotheses:

Hypothesis 3: There is a curvilinear relationship between knowledge depth and new knowledge acquisition in the subsequent period such that individuals will acquire more new knowledge components when their knowledge depth is at intermediate levels than when it is at lower or higher levels.

Hypothesis 4: There is a curvilinear relationship between knowledge depth and the number of new collaborative ties formed in the subsequent period such that individuals will form more new ties when their knowledge depth is at intermediate levels than when it is at lower or higher levels.

The Number of New Ties as a Mediator between Knowledge Stock and Knowledge Acquisition

Conceptualized as pipes that carry resources such as knowledge and ideas, social networks have been well established as facilitative of knowledge acquisition and creation. By interacting with others, individuals exchange and combine overlapping and diverse knowledge inputs. Such interactions help individuals to build a better understanding of how things work and how exchange partners think and gain new insights (McFadyen et al., 2009; Polanyi, 1966). Hence, I believe that new ties are central to knowledge acquisition as

new ties are more likely to introduce different and diverse information. As previously highlighted, new ties are characterized by very short history of interaction and lack of shared experience. Relative to repeated ties, new ties are unlikely to have the risk of homogenization of common knowledge (Uzzi & Spiro, 2005). In fact, new ties are more likely to be dissimilar to ego, and hence expose ego to more novel information and perspectives, thereby facilitating acquisition of new knowledge.

I have argued in this paper that a knowledge stock with higher knowledge breadth and moderate level of knowledge depth provides a more robust basis for learning in uncertain situations, thus leading to advantages in knowledge acquisition. I have also argued that pre-existing knowledge stock influences the number of new ties one can successfully form. Scholars with greater knowledge breadth and moderate level of knowledge depth are not only more attractive to others as potential collaborators, but also more effective in communication and knowledge exchange in any new encounter due to higher knowledge absorptive and transfer capacity, which leads to higher volume of new ties one can successfully establish. By forming more new ties, scholars are advantaged in getting access to more new information, thus fostering their acquisition of new knowledge.

Thereby, I posit the following hypotheses:

Hypothesis 5: The number of new ties one forms is positively associated with new knowledge acquisition.

Hypothesis 6: The number of new ties one forms partially mediates the positive relationship between knowledge breadth and new knowledge acquisition.

Hypothesis 7: The number of new ties one forms partially mediates the curvilinear relationship between knowledge depth and new knowledge acquisition.

METHODS

Data and sample

To test the hypotheses, I collected longitudinal data on a sample of psychologists using PsycINFO database. There is a trend towards increasing collaboration in social sciences. Moody (2004) found significant growth in coauthorship in the 1989-1999 period comparing with the 1975-1985 period. Hence, I decided to focus my data collection in recent two decades from 1990 to 2010. Specifically, the sample of psychologists was drawn in two steps. In the first step, I drew a random sample of 600 journal articles published in 1990. I then sifted out all unique author's names from this publication pool, resulting in over 1400 authors. In the second step, I searched for the publication records for each scholar in the list across their entire career. As I am interested in research-active psychologists, those who published only one or two articles during the period from 1990 to 2010 were excluded from the list, which reduced the sample to 416 authors.

Data were obtained from two sources. First, to construct each scholar's knowledge structure and collaborative network, I used PsycINFO database to extract each psychologist's co-authorship publication records across their entire career thus far. PsycINFO is the largest database devoted to peer-reviewed literature in psychology and related disciplines. A key advantage of PsycINFO is that all records in this database from 1967 to the present are indexed by experts with controlled vocabulary from American Psychological Association (APA)'s *Thesaurus of Psychological Index Terms*. Standardizing the words or phrases used to represent concepts allows me to compare concepts across authors. In my dataset, the number of assigned knowledge concepts per article ranges from 1 to 12, with an average of 5.3, which is relatively constant through the twenty-one years I examined. In addition, PsycINFO displays full names of the authors in their publication records, making name matching relatively easier compared with in other databases where only the last name and initials are available. I consider two authors to be the same if and only if (1) there was an exact match on the author's first and last names, and (2) the middle initials, if available, were the same. I further verified ambiguous items by checking the author's address and affiliation printed in the publication to decide if that publication should be grouped under a particular author name. I downloaded the publication records for each scholar in my sample. For each article, year of publication, index terms and every co-author's name were coded.

Second, data regarding citation counts of each scholar across their entire career were obtained from ISI Web of Science. I chose ISI Web of Science

instead of PsycINFO to obtain citation data because cited references in PsycINFO only began in 2001 while ISI Web of Science provides more comprehensive citation records dating back to early 1900 (Fingerman, 2006). I used same name matching criteria as I did in data collection from PsycINFO. Additionally, I manually reviewed difficult cases by crosschecking one's publications listed in ISI Web of Science with those I obtained from PsycINFO to ensure accurate name matching.

Consistent with prior research on social networks (Cattani & Ferriani, 2008; Fleming et al., 2007; Nerkar & Paruchuri, 2005), I split the data into three-year periods for each scholar's career. The model analyzed six non-overlapping windows: 1993-1995, 1996-1998, 1999-2001, 2002-2004, 2005-2007, and 2008-2010. However, my sample starts from 1990 as the first three years of data (1990-1992) are used for measurement of the independent and control variables. Redefining the time window, for example, considering the set of windows starting with 1994-1996 and 1995-1997, did not change the results.

Measures

New collaborative ties. New ties are defined as a focal scholar's collaborative ties whom the focal scholar has no prior collaborative relationship with. To identify new ties, I include all past connections in a focal scholar's collaborative network, assuming that any prior connection, no matter how long ago it took place, would affect current behavior (Gulati, 1995). Specifically, I include a focal scholar's all collaboration activity that had occurred until the

year before a given year t , and count the number of novel collaborative ties in the time period from year t to $(t+2)$.

New knowledge acquisition. Knowledge acquisition captures the extent to which new knowledge is acquired and integrated into one's existing knowledge stock (Katila & Ahuja, 2002). I measured knowledge acquisition by counting new knowledge concepts that are first included into one's knowledge portfolio in a three-year time window. To determine new knowledge concepts from year t to $(t+2)$, I compared the index terms that was assigned to one's publications in the focal time window with those obtained from his/her prior publications before year t . I then counted the number of new index terms that were not previously included in the focal scholar's knowledge stock in each three-year window.

Knowledge breadth and depth. I used publication data to obtain measures of the breadth and depth of scholars' knowledge stock. Publication records in PsycINFO database are indexed by subject experts at APA. The thesaurus used to index the publications includes more than 8,400 standard and cross-referenced terms. Each publication is indexed with most specific terms applicable, with a maximum of 15 total terms. Each subject term therefore represents a technical domain that a scholar works on. I define a focal scholar's knowledge stock at a given year t as including all his/her publications prior to year t . I first recorded assigned index terms for each publication, and then compiled all the index terms across publications, which form a scholar's knowledge stock.

Knowledge breadth reflects the range of a scholar's knowledge portfolio. It was measured as the number of unique subject terms assigned to the focal scholar's publications (Boh et al., 2014; Fleming et al., 2007). The number of different subject areas in which a scholar has publications would suggest the broad distribution of technical knowledge a scholar has.

Knowledge depth is conceptualized as the thoroughness of a focal scholar's knowledge in his/her specialized areas. Depth of knowledge is generally associated with repeated usage and increased experience (Levinthal & March, 1993). Adopting the same measure used by Boh et al. (2014), I first identified the scholar's core domain area, which is defined as the subject term that the scholar's publications cite most frequently. I then computed the scholar's knowledge depth as the total number of articles the focal scholar has published in his or her core domain area, divided by the scholar's total number of publications. This measure effectively assesses the portion of articles published by a focal scholar that is indexed with the subject term that the focal scholar's publications cite most frequently.

Control variables. I also included controls for several variables that might affect the hypothesized relationship, including research productivity, experience, and network size.

First, I controlled for *research productivity*. Prior research productivity could affect tie formation as scholars of higher research productivity are more visible to the potential collaborators and are also more likely to be considered as attractive partners. Furthermore, research productivity might also impact

one's access to new knowledge. Being more prestigious and respected in the field, scholars of higher productivity are likely to receive more opportunities such as invited presentations at conferences and seminars, editorial board positions, and visiting professorship positions, which might lead to enhanced exposure to new knowledge. Research productivity was operationalized using two measures – publication counts to reflect research quantity and citation counts to reflect research quality (Long et al., 2009). I used counts of journal articles a focal scholar published prior to the current time window analyzed as a proxy for research quantity. Book reviews, letters to the editor, replies, comments and similar writing were excluded from the publication count. The number of citations for each publication – up to the current time window analyzed – that a scholar received in the ISI Web of Science was used as a proxy for research quality. As the distribution of publications and citation counts were highly skewed, I employed log transformation to achieve a normal distribution.

I included the scholars' *Experience* in academia to capture variance in human capital. Furthermore, this variable allowed me to control for the greater opportunities for coauthorships and increased sources to obtain new knowledge for scholars with longer tenure in the field. *Experience* is measured as the number of years from the year in which scholars published their first article to the year before the focal time window analyzed.

I also controlled for network size by counting the total number of co-authors with whom a scholar had collaborated in the three-year time window

preceding tie formation, because the size of collaborative network not only affects the number of potential new collaborators through referrals but also one's access to novel information.

Finally, I controlled for cohort fixed effects in all my models to capture systematic period effects and unobserved heterogeneity across time. *Cohort* was coded as dummy variables for each three-year time period from 1990, except for the reference group.

Statistical Methods

My sample contains time series cross-sectional panel data consisting of scientific publications for 416 psychologists over 21 years. The unit of analysis is a scholar in a given time window, and there are a total of 2440 scholar time-period observations. I chose the fixed effects model to control for unobserved, individual-specific factors (e.g., demographic factors, personality, intelligence, etc.) that might otherwise affect scholars' tie formation or knowledge acquisition (Baltagi, 2001). Because the two dependent variables in this study – *New Collaborative Ties* and *New Knowledge Acquisition* – are both operationalized as count variables, taking only integer and positive values, Poisson or negative binomial models are recommended (Hausman, Hall, & Griliches, 1984). The Poisson distribution contains the strong assumption that its mean and variance are equal. When this assumption does not hold, coefficients will be estimated consistently, but standard errors might be underestimated and chi-square value statistics overestimated (Cameron & Trivedi, 1998). A commonly used alternative to the Poisson model is the

negative binomial mode, which allows for overdispersion of the variance in the dependent variable by introducing an individual unobserved disturbance (Cameron & Trivedi, 1998; Hausman et al., 1984). The estimation of the overdispersion parameter alpha (α) for each estimated model suggested that negative binomial estimation is more suitable than Poisson. In fact, the estimated overdispersion parameter alpha (α) is significantly different from zero in each model ($p < 0.001$).

However, Allison and Waterman (2002) have criticized the commonly used conditional negative binomial estimator with fixed effects (Hausman et al., 1984) as not being a “true” fixed-effects method in that it does not necessarily control for all stable individual effects. Following Allison and Waterman’s recommendation, I employed unconditional negative binomial models that include dummy variables to represent fixed effects, which effectively control for all unobserved time-invariant individual effects. I also used Hausman et al. (1984) conditional fixed-effects approach and found very similar results. I estimated the models by using the ‘nbreg’ routine included in the STATA software package Version 12 (StataCorp, College Station, TX). The results using unconditional negative binomial specification are reported in the following section.

RESULTS

Table 4 presents the means, standard deviations, and correlations for the variables used in the analyses. As a check for multicollinearity, variance inflation factor (VIF) scores were calculated for the variables in each regression model. All VIF scores were below 5, and most were below 2, suggesting that multicollinearity was not a serious problem in the analysis. Furthermore, as several authors have recommended, I centered the variable *Knowledge depth* on its mean before creating the squared term to minimize potential multicollinearity problems (e.g., (Cronbach, 1987).

I ran hierarchical regressions to test the hypotheses. Table 5 presents the results for how knowledge breadth and depth affect the number of new ties formed in the subsequent three-year time window. Model 1 includes just the control variables. I then entered knowledge breadth and depth into the regression analysis in Model 2, and knowledge depth squared in Model 3. Similarly, Table 6 reports the regression results for the number of new knowledge components acquired in the subsequent three-year time window. Model 5 was first examined with only the control variables. Model 6 added the main variables – knowledge breadth and depth, and then the squared term of knowledge depth in Model 7. Finally, I included in Model 9 the mediating variable – the number of new ties. I used the likelihood ratio post-estimation test to analyze model improvement, and significant improvement was always observed ($p < 0.001$).

Insert Table 4 about here

Hypothesis 1 posits a positive relationship between knowledge breadth and new knowledge acquisition in the subsequent period. I found initial support in Model 6. However, the significantly positive effect of knowledge breadth on knowledge acquisition disappeared after the squared term of knowledge depth was entered into the regression in Model 7. In addition, in Model 9, which is the full model, I failed to find significant effect of knowledge breadth. Hence, I considered Hypothesis 1 not supported. Hypothesis 2 was supported, which postulated that knowledge breadth have a positive effect on the number of ties formed in the subsequent period. I found consistent evidence of this effect in Model 2 ($\beta = 3.09, p < 0.001$) and Model 3 ($\beta = 1.42, p < 0.05$).

In Hypothesis 3, I propose that knowledge depth will have a curvilinear (inverted U-shaped) relationship with new knowledge acquisition in the subsequent period. As indicated in Model 9, the coefficient for knowledge depth is positive and significant and that for the squared term of depth is negative and significant ($\beta = 2.17, p < 0.001$; $\beta = -5.15, p < 0.001$, respectively), supporting Hypothesis 3. Hypothesis 4 proposes an inverted U-shaped relationship between knowledge depth and the number of new collaborative ties in the subsequent period. Results in Model 3 shows that both the linear and squared terms are highly significant and in the expected direction

($\beta = 2.59, p < 0.001$; $\beta = -5.77, p < 0.001$, respectively), providing full support for Hypothesis 4.

Insert Tables 5 and 6 about here

Hypothesis 5 predicts that the number of new ties is positively related to new knowledge acquisition. Model 9 presents a significantly positive impact of new ties on the number of new knowledge concepts acquired ($\beta = 0.04, p < 0.001$), in support of Hypothesis 5.

Next I examined the mediating effects of new ties. Kenny, Kashy, and Bolger (1998; MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002) laid out some ground rules for establishing mediation. According to these rules, the number of new ties qualifies as a mediator because (a) it is significantly related to the independent variable (in this case, knowledge breadth and depth, see Model 3), and (b) it is significantly associated with the dependent variable (new knowledge acquisition, see Model 9). To demonstrate mediation, two additional requirements are (c) that the independent variable is correlated with the dependent variable, and (d) the independent variable no longer exerts significant influence on the dependent variable when the mediator is included in the model. In the case of knowledge breadth, I failed to find support for its direct relationship with knowledge acquisition. Hence, Hypothesis 6 was not supported. With regard to knowledge depth, I have demonstrated that it is related to both knowledge acquisition and new ties in curvilinear fashions

(Hypothesis 3 and 4). I then repeated the regression analysis used to test Hypothesis 3 with the number of new ties added as a control. After controlling for the number of new ties, both the linear and the squared term for knowledge depth are still significant as shown in Model 9 ($\beta = 2.17, p < 0.001$; $\beta = -5.15, p < 0.001$, respectively), but the coefficients are lower in magnitude than the coefficients in Model 7 ($\beta = 2.63, p < 0.001$, for the linear term; $\beta = -5.82, p < 0.001$, for the squared term), indicating partial mediation. In addition, I conducted the Sobel test (Sobel, 1982) for knowledge depth, the results of which confirm the partial mediating effects ($z = -8.55, p < 0.001$). Thus, in support of Hypothesis 7, new ties partially mediated the relationship between knowledge depth and knowledge acquisition.

Robustness Checks

I conducted several additional analyses to probe the validity of my findings. First, to check the robustness of my results of windows of a different length, I conducted the same analyses using window length of four years, five year and six years respectively, since the time taken to initiate and successfully publish a research paper can extend beyond three years in some cases. Although the pattern of results across these analyses remained largely the same, my three-year windows provided the best fit, which is consistent with previous research (Fleming et al., 2007; Long, 1978; McFadyen et al., 2009; Nerkar & Paruchuri, 2005).

Second, prior research has used the Herfindahl index², which captures the extent to which a scholar's publications are concentrated in one domain area, or equally distributed across different domain areas, to measure knowledge structure (Gruber, Harhoff, & Hoisl, 2013; Lahiri, 2010). I also computed this measure and found it positively correlated with knowledge depth ($r = 0.13, p < 0.001$) and negatively correlated with knowledge breadth ($r = -0.43, p < 0.001$). This suggests that the Herfindahl index (HI) is in effect a measure of both the depth and breadth of a scholar's knowledge structure (Boh et al., 2014). A scholar with greater knowledge depth would have a higher HI (close to 1), while a scholar with greater knowledge breadth would have a lower HI (close to $1/N$). As I consider breadth and depth as two distinct dimensions of one's knowledge structure in this article, my current breadth and depth measures as independent measures of knowledge structure are more appropriate.

Third, I have defined *Knowledge Depth* as the number of publications a scholar published in his or her core domain area – the subject area that the scholar's publications cite most frequently, divided by the scholar's total number of publication. One might suggest that some scholars have expertise that spans more than one domain. To capture such situations, I conducted further sensitivity analysis by defining one's core knowledge domains as the two or three subject terms that a scholar's publications cite most frequently, and the results remain unchanged.

² Herfindahl index, is measured by $H = \sum_{i=1}^N s_i^2$, where S_i is the proportion of a scholar's articles published in domain area i , and N is the total number of domain areas that the scholar has published in.

Fourth, I posit that the number of new ties mediates the relationship between knowledge structure and new knowledge acquisition. This is based on the notion that new ties are central to knowledge acquisition as new ties serve as conduits to different and diverse knowledge and ideas. However, another plausible argument is that new knowledge acquisition mediates the relationship between knowledge structure and the number of new ties. As I have found that knowledge acquisition is significantly related to knowledge depth but not breadth, I further tested the alternative mediating effect with regard to knowledge depth. I repeated the regression analysis used to test Hypothesis 4 with knowledge acquisition added as a control. Knowledge acquisition was not found to mediate the relationship between knowledge depth and the number of new ties.

Fifth, I accounted for the fact that a scholar's forming a collaboration tie or citing a new domain area at time t is conditioned upon the scholar's publishing at least one collaborative article at t . Not every scholar has the same ability or propensity to publish a collaborative article at a particular period. At the same time, a scholar's propensity to collaborate may also correlate with one's knowledge stock. Failures to account for the differences in the publication hazard may result in biased estimates. Hence, to control for the possibility of selection bias, I first ran a probit model and then included the *selection hazard* – i.e. the inverse Mill's ratio – as a regressor in the new ties models as well as the knowledge acquisition models (Heckman, 1979). The ratio essentially controls for the probability that the scholar will produce at least one

collaborative article. The dependent variable in the selection model takes 1 if the scholar published a collaborative article at t and 0 otherwise. For the explanatory variables, I used *prior citation counts*, *prior publications*, *network size*, *knowledge breadth*, *knowledge depth*, and *the proportion of coauthored publications*. The last variable was computed as the number of collaborated publications divided by the total number of articles authored by the scholar, which captures the proclivity to collaborate on publication authorship (Lee, 2010). *Cohort* dummies were also included in the selection model. As shown in Model 4, 8 and 10, both new ties and knowledge acquisition results were robust to the inclusion of the selection hazard.

DISCUSSION

How does individual knowledge structure influence the formation of new ties? How does the number of new ties mediate the effect of individual knowledge structure on knowledge acquisition? I investigated these research questions in a longitudinal data set of 416 academic scholars in the Psychology discipline by tracking their collaborative networks in twenty-one years.

I theorize that an individual's pre-existing knowledge can serve as a signal to others of one's underlying competence; more importantly, it can influence the ease of communication and efficiency of knowledge exchange through one's capacity to absorb and transfer knowledge, thereby affecting the likelihood of an initial encounter to become a successful collaboration. My

study did provide evidence that the actor-level heterogeneity in knowledge structure can predict the number of new ties scholars form in the subsequent time period. In particular, I focused on the breadth and depth of one's existing knowledge stock. I found that knowledge breadth is positively associated with the amount of new ties one forms. This finding suggests that as knowledge breadth grows, people are likely to form more new ties as their knowledge diversity increases the possibility that they could have knowledge overlap with a potential partner, which enhances knowledge absorption and transfer. I also found knowledge depth to be curvilinearly related to the amount of new ties one forms in the subsequent time period, assuming the shape of an inverted U. This pattern of results implies that knowledge depth has both upside and downside. Specifically, as knowledge depth initially grows, a scholar is likely to form more new ties as the depth of knowledge increases one's ability to absorb new knowledge via analogical reasoning and transferability of learning skills and also effectively transfer his or her ideas to a new contact, thus increasing the efficacy of communication and knowledge exchange. However, when depth of knowledge reaches a certain level, the scholar tends to search locally and becomes less inclined to seek new sources of knowledge. Meanwhile, compared with his or her less specialized peers, a highly specialized scholar has to invest more attention and time in knowledge exchange with potential partners due to enlarged cognitive distance between his or her own expertise and others' specializations. Increased difficulties and costs incurred in

knowledge transfer with potential collaborators would reduce the amount of new ties one eventually secures.

In addition, I found that the amount of new ties is positively associated with the amount of new knowledge components incorporated into one's knowledge base. This result is consistent with general argument that new ties foster knowledge acquisition by functioning as pipes that carry different and diverse information due to the lack of shared history and experience. Furthermore, I examined whether new ties mediate the relationships between existing knowledge stock and knowledge acquisition. Some evidence was obtained for the hypothesized mediating process for knowledge depth. It was argued that scholars with low levels of knowledge depth has limited cognitive ability in knowledge exchange with new partners, and that when scholars have overly high levels of knowledge depth, the risk of knowledge myopia in the search process is more likely and transfer of knowledge and skills across knowledge bodies becomes increasingly difficult due to enlarged cognitive distance. In both cases, scholars are likely to form limited new ties, constraining their access to new knowledge. At moderate levels of knowledge depth, however, scholars are likely to be capable and motivated to engage with more new collaborators, which enhances their access to novel information and thus facilitates their acquisition of new knowledge. The general picture that emerged is that knowledge depth relates to the amount of new ties in a curvilinear fashion, that new ties facilitate knowledge acquisition, and that new ties partially mediate the relationship between knowledge depth and knowledge

acquisition. The partial mediation suggests that new ties are responsible for only part of the effects of knowledge depth on knowledge acquisition. For scholars with moderate levels of knowledge depth who are motivated and capable to search for and absorb new knowledge, it is not only by connecting with others that they can access and acquire new knowledge, but also by conducting solo activities such as reading literature and running experiments.

However, I failed to find support for the mediating effects of new ties on the relationship between knowledge breadth and knowledge acquisition. Inconsistent with my expectation, knowledge breadth has no direct effect on knowledge acquisition.³ Hence, there is no “effect to be mediated” in the first place (Kenny, 2014; Preacher & Hayes, 2004). It was argued that breadth in knowledge extend the chance that incoming knowledge is related to existing knowledge, thus enhancing knowledge acquisition. Especially under pressure to publish, scholars would be motivated to acquire new knowledge because a large pool of knowledge would increase recombinant opportunities. However, the relationship between knowledge breadth and knowledge acquisition might be more complex. It could be that some people with knowledge breadth are reluctant to explore new area and instead prefer experimenting with their current knowledge pool since they have the requisite variety for recombinant opportunities. Future research can explore the different strategies people might adopt in knowledge acquisition depending on their breadth of knowledge.

³ I also tested potential quadratic effects of knowledge breadth on knowledge acquisition, but did not find consistent results.

Overall, my study contributes to social network research by demonstrating that the relationship between networks and knowledge is not unidirectional. Majority of research in this area has focused on how network relationships influence knowledge outcomes (Burt, 2004; Hansen, 1999; McFadyen & Cannella, 2004; Reagans & McEvily, 2003). Along the same line of thought, I found that the amount of new ties one establishes is associated with the number of new knowledge components he or she acquires. More importantly, my findings showed a reversed causality that individuals' existing knowledge could affect subsequent formation of new ties. In particular, with greater knowledge breadth and moderate level of depth, people will be more motivated and have higher cognitive abilities to have meaningful initial conversations with someone who they are not familiar with, thus increasing the likelihood of an initial encounter to result in a successful collaboration. Taken together, my findings suggest that there can be bidirectional dynamics between individual knowledge and network formation such that people with adequate knowledge breadth and depth are more apt to form new ties, which in turn will lead to more new knowledge.

Limitations and Future Research

As I constructed collaborative ties using co-authorship in publications, a limitation of my study is that unpublished collaborative ties are not observed. Even though prior studies using publications or patents to reconstruct collaborative ties suffer from the same limitation (e.g., (Melin & Persson, 1996; Newman, 2001a, b), there is the risk of incompleteness in my dataset since new

collaborative ties that did not lead to a publication were excluded from my dataset. Yet, I find no a priori reason to expect unpublished new collaborative ties to systematically correlate with prior knowledge structure in such a way that would bias my current set of findings. In addition, in their study on formation of new ties and repeated ties, Dahlander and McFarland (2013) analyzed grant applications (including both failed and successful attempts) and found very consistent results with those on publication data, offering support to the notion that published articles afford a visible trail of research collaborations I can follow.

My sample comprises of academic scholars in the field of Psychology, raising a concern over the generalizability of the findings. Psychology is a discipline that encompasses a vast domain and includes many diverse approaches to the study of mental processes and behavior. Scholars from different subfields may share some baseline level of knowledge but also specialize in distinct directions. These characteristics of the Psychology discipline can lead to findings that may not be replicable in settings where the subfields are not closely related and shared disciplinary knowledge is lacking. For example, in disciplines with very specialized subfields such as Physics, knowledge absorption from and transfer to different subfields can be much more difficult. This points to the opportunity for future research to extend my inquiry to other academic communities, because my findings may depend on specific research regimes characterizing a given field.

I examined the effects of existing knowledge structure on the formation of new ties. Prior knowledge could influence other features of social networks such as brokerage positions and core-periphery structures. For example, individuals with certain knowledge breadth and depth may be more apt to form collaboration ties that lead them to occupy brokering positions. Future research should extend this investigation by examining how an individual's knowledge structure affects the structural configurations of his or her collaborative networks. In addition, I mainly focused on the intrapersonal knowledge structure of the focal scholar. Future studies may encompass the knowledge portfolios of the collaborators of the focal scholars and further explore whether one's knowledge pattern will predict the 'cognitive' composition of his or her network and whether such relationship will be mediated by different network configurations.

Practical Implications

My study offers interesting practical implications for scientists and research scholars. First, my findings reveal that adequate knowledge stock is beneficial to the formation of new ties. To expand their collaborative networks, scientists and research scholars should increase the breadth and depth of their knowledge stock, because adequate knowledge stock will translate into higher knowledge absorptive and transfer capacity, thereby enhancing the possibility of an initial encounter to become a successful collaboration. Second, while sufficient knowledge depth is essential to the formation of new ties and the acquisition of new knowledge, overly high level of knowledge depth could

become detrimental because of the motivational barriers (i.e., knowledge myopia) as well as the knowledge absorption and transfer barriers. Hence, scientists and scholars should be aware of this double-edged sword effect and avoid concentrating all their time and efforts on one or a limited few research subjects. Third, my study highlights that forming new ties are indeed an effective way to access new information and ideas, which are critical for knowledge creation. Hence, to acquire new and diverse knowledge, scientists and scholars should expand their networks by forming more new ties instead of just repeating existing ties that tend to circulate redundant information.

CONCLUSION

Social networks play a critical role in knowledge creation and transfer. While a large and growing body of research has provided significant evidence on how social relationships and the networks they constitute affect the efficacy and efficiency of knowledge exchange and creation, little is known about how social networks are formed, and empirical work is particularly lacking. Using data on samples of academic scholars, this dissertation investigates the origins of academic collaborative networks.

Drawing from both the structural and agentic perspectives on the formation of social networks, Essay One focuses on how the formation of collaborative networks is influenced by the joint effects of organizational setting and individual productivity in the early career of academic scholars. Focusing on a sample of academic scholars in Management field, I found that structural conditions and individual factors both matter in forming collaborative networks. On the one hand, the significant associations between institutional prestige and scholars' subsequent collaborative networks provide support for the structural view that institutions provide opportunities or constraints for their members to form certain ties. On the other hand, I found evidence on the moderating role of individual productivity in forming internal collaborative networks. Contrary to my expectation, less productive scholars are actually more motivated to actively appropriate the non-redundant knowledge and

opportunities within prestigious institutions by cultivating sparse internal networks.

Essay Two investigates how individuals' internal knowledge structure influences the formation of new ties and how the amount of new ties mediates the effect of knowledge structure on new knowledge acquisition. While most of prior research on social networks has focused on how network relationships affect knowledge outcomes, the findings provide evidence that the relationship between networks and knowledge is not simply unidirectional. The results not only confirm a positive relationship between the amount of new ties and new knowledge acquisition, but also show a reverse causality that individuals' existing knowledge could affect subsequent formation of new ties. Taken together, these findings suggest that there can be bidirectional dynamics between individual knowledge and network formation in that people with adequate knowledge stock have higher motivation and cognitive capacity to absorb and transfer knowledge and are hence more apt to form new ties, which in turn will lead to more new knowledge.

In general, in contrast of the structural view that individual social networks are constrained by the limit of their social conditions, this dissertation highlights that individuals help shape the social networks they inhabit. In particular, differences in individual human capital factors play important roles in the formation of social networks, as a contingency factor or a direct predictor.

First, as a contingency factor, individual differences can influence how

individuals leverage the resources presented in their social settings to form network ties. While acknowledging the significant influence of social conditions on individuals' social networks, Essay One highlights that individuals can be active agents in orchestrating their social networks within the constraints of the resources available in their work organizations. The findings show evidence that individual productivity moderates the effects of institutional prestige on scholars' collaborative networks, in particular with regard to their internal network structure. Specifically, compared with their peers who are higher in past productivity, less productive scholars are more motivated to develop sparser networks in prestigious institutions. It is plausible that less productive scholars in prestigious institutions have greater pressure to publish, due to the more competitive peer environment and higher performance standards at more prestigious institutions, and thus cultivate sparser networks to obtain non-redundant information for knowledge creation. This finding suggests that while prestigious institutions offer more economic and instrumental resources, scholars may not be equally agentic in forming efficient network ties to appropriate these resources.

Second, individual differences can be a direct predictor of network formation. In particular, Essay Two highlights that individuals differ in their cognitive ability to form new ties. Integrating cognitive and social network perspectives, I argue that individuals' pre-existing knowledge can influence their capacity to absorb from and transfer knowledge to potential partners, thereby affecting the likelihood of an initial encounter to become a successful

collaboration. Specifically, the results show that knowledge breadth is positively associated with the amount of new ties one forms, and that knowledge depth is curvilinearly related to the amount of new ties one forms assuming an inverted U shape. These results suggest that with other things being equal, individuals with adequate knowledge stock are more advantaged in forming new ties.

Overall, connecting social network perspective with human agency and cognitive perspectives, this research contributes to shedding light on how individual collaborative networks are formed; it also provides implications on how individuals should form their collaborative networks to acquire social and intellectual capital to achieve their career-enhancing goals.

APPENDIX

Scopus Author Identifier⁴

Many authors have similar names. The Scopus Author Identifier distinguishes between these names by assigning each author in Scopus a unique number and grouping together all of the documents written by that author. This feature is especially useful for distinguishing between authors who share very common names like Smith or Wang or Lee.

Additionally, author names in Scopus can be formatted differently. For example, the same author could appear in one document as Lewis, M; in another as Lewis, M.J; and in another as Lewis, Michael. Scopus Author Identifier matches the documents of this author and groups these name variants together so that authors, even if cited differently, are identified with their specific papers. This helps users find and recognize an author, despite variations in name spelling.

To determine which author names should be grouped together under a single identifier number, the Scopus Author Identifier uses an algorithm that matches author names based on their affiliation, address, subject area, source title, dates of publication citations, and co-authors.

⁴[http://help.elsevier.com/app/answers/detail/a_id/2845/p/8150/incidents.c\\$portal_account_name/47479](http://help.elsevier.com/app/answers/detail/a_id/2845/p/8150/incidents.c$portal_account_name/47479)

TABLES

TABLE 1
Descriptive Statistics and Correlations (Essay One)
(N = 293)

Variable	Mean	s.d.	1	2	3	4	5
1 Proportion of external ties r^a	0.61	0.43					
2 Internal network density r	0.09	0.28	-0.50 ***				
3 Institutional prestige	4.04	0.83	0.19 *	-0.15 **			
4 Past productivity ^b	0.82	2.70	-0.07	0.26 ***	-0.03		
5 Number of external ties r	0.67	1.38	0.52 ***	0.20 ***	-0.06	0.11	
6 Doctoral prestige	4.37	0.65	0.04	-0.12 *	0.42 ***	-0.02	-0.11
7 Gender	0.79	0.41	-0.01	-0.07	-0.03	0.04	-0.02
8 Research awards r_{-1}	0.18	0.38	-0.01	0.12 *	0.03	0.06	0.14 *
9 Editorial position r_{-1}	0.02	0.14	-0.02	0.09	-0.04	-0.04	0.02
10 Network size r_{-1}	0.44	1.13	-0.17	0.29 ***	-0.13 *	0.62 ***	0.26 ***
11 Number of external ties r_{-1}	0.14	0.55	-0.02	0.16 **	-0.08	0.31 ***	0.23 ***
12 Internal network density r_{-1}	0.07	0.24	-0.17	0.30 ***	-0.04	0.54 ***	0.13 *

^a n = 151.

^b Cumulative scores until the year before the beginning year of time window T .

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

TABLE 1 (continued)
Descriptive Statistics and Correlations (Essay One)
(N = 293)

Variable	6	7	8	9	10	11
7 Gender	0.02					
8 Research awards T_{-1}	0.04	-0.03				
9 Editorial position T_{-1}	-0.03	-0.01	0.08			
10 Network size T_{-1}	-0.21 ***	-0.10	0.10	-0.04		
11 Number of external ties T_{-1}	-0.20 ***	-0.07	0.12 *	-0.03	0.71 ***	
12 Internal network density T_{-1}	-0.06	-0.05	0.06	-0.03	0.70 ***	0.17 **

^a n = 151.

^b Cumulative scores until the year before the beginning year of time window T .

* $p<0.05$

** $p<0.01$

*** $p<0.001$

TABLE 2

Regression Analysis Results for Proportion of External Ties in time window T ^a
(Essay One)
(N = 151)

Variable	Model 1		Model 2		Model 3	
Intercept	0.49	(0.27)	0.74 **	(0.28)	0.75 **	(0.29)
Network size T_{-1}	-0.05	(0.03)	-0.05	(0.03)	-0.05	(0.03)
Number of external ties T_{-1}	0.12 *	(0.06)	0.11 *	(0.06)	0.11 *	(0.06)
Gender	-0.01	(0.08)	0.01	(0.08)	0.01	(0.08)
Research awards T_{-1}	-0.02	(0.08)	-0.01	(0.08)	-0.01	(0.08)
Editorial position T_{-1}	-0.03	(0.18)	-0.04	(0.17)	-0.04	(0.17)
Doctoral prestige	0.03	(0.06)	-0.03	(0.06)	-0.03	(0.06)
Past productivity ^b	-0.01	(0.01)	-0.01	(0.01)	-0.01	(0.01)
Institutional prestige			0.10 *	(0.04)	0.10 *	(0.04)
Institutional prestige $\times$ Past productivity ^b					0.01	(0.01)
Wald χ^2	5.60		11.33 *		11.34	

^a Standard errors are in parentheses.

^b Cumulative scores until the year before the beginning year of time window T .

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

TABLE 3

Regression Analysis Results for Internal Network Density in time window T ^a
(Essay One)
(N = 293)

Variable	Model 4			Model 5		Model 6	
Intercept	0.27	*	(0.11)	0.18	(0.12)	0.17	(0.12)
Network size T_{-1}	0.02		(0.02)	0.01	(0.02)	0.02	(0.02)
Gender	-0.04		(0.04)	-0.04	(0.04)	-0.03	(0.04)
Research awards T_{-1}	0.07		(0.04)	0.07	(0.04)	0.07	(0.04)
Editorial position T_{-1}	0.28		(0.15)	0.28	(0.15)	0.28	(0.15)
Internal network density T_{-1}	0.20	*	(0.09)	0.20	*	0.22	** (0.09)
Doctoral prestige	-0.04		(0.02)	-0.02	(0.03)	-0.02	(0.03)
Past productivity ^b	0.01		(0.01)	0.02	(0.01)	0.01	(0.01)
Institutional prestige				-0.04	*	-0.03	(0.02)
Institutional prestige $\times$ Past productivity ^b						0.02	* (0.01)
Wald χ^2	46.24	***		51.22	***	56.69	***

^a Standard errors are in parentheses.

^b Cumulative scores until the year before the beginning year of time window T .

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

TABLE 4
Descriptive Statistics and Correlations^a (Essay Two)

Variable	Mean	s.d.	1	2	3	4	5	6	7
1 New knowledge acquisition _T	10.07	12.70							
2 New collaborative ties _T	8.23	14.85	0.77 ***						
3 Knowledge breadth ^b	67.96	56.76	0.44 ***	0.42 ***					
4 Knowledge depth ^b	0.49	0.23	-0.05 *	0.01	-0.42 ***				
5 Research quality ^{b,c}	2.11	0.93	0.28 ***	0.30 ***	0.67 ***	-0.28 ***			
6 Research quantity ^{b,c}	1.20	0.46	0.47 ***	0.54 ***	0.78 ***	-0.17 ***	0.58 ***		
7 Experience ^b	17.73	8.51	0.11 ***	0.15 ***	0.61 ***	-0.41 ***	0.54 ***	0.50 ***	
8 Network size _{T-1} ^c	0.67	0.54	0.58 ***	0.57 ***	0.67 ***	-0.09 ***	0.42 ***	0.63 ***	0.24 ***

^a n = 2440.
^b Cumulative scores until the year before the beginning year of time window *T*.
^c Logarithm.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

TABLE 5
Results of Negative Binomial Regression Analysis for the Number of New Collaborative Ties in time window T^a (Essay Two)
(N = 2440 observations, 416 individuals)

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	0.50 (0.44)	-2.00 *** (0.60)	-0.63 (0.61)	-1.25 (0.83)
Research quality ^{b,c}	0.28 * (0.12)	0.36 ** (0.12)	0.29 * (0.12)	0.28 * (0.12)
Research quantity ^{b,c}	-0.41 (0.33)	-2.91 *** (0.62)	-1.57 * (0.63)	-1.72 ** (0.64)
Experience ^b	0.03 *** (0.01)	0.03 *** (0.01)	0.05 *** (0.01)	0.04 *** (0.01)
Network size T_{-1} ^c	0.26 ** (0.08)	0.21 * (0.09)	0.17 * (0.09)	0.32 * (0.16)
Knowledge breadth ^b		3.09 *** (0.62)	1.42 * (0.64)	1.76 * (0.71)
Knowledge depth ^b		2.03 *** (0.24)	2.59 *** (0.26)	2.84 *** (0.34)
Knowledge depth squared ^b			-5.77 *** (0.61)	-5.76 *** (0.61)
Selection hazard				0.39 (0.35)
Log likelihood	-6133.78	-6097.17	-6050.25	-6049.61

^a Standard errors are in parentheses. Individual dummies and cohort dummies were included but are not shown.

^b Cumulative scores until the year before the beginning year of time window T .

^c Logarithm

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

TABLE 6
Results of Negative Binomial Regression Analysis for New Knowledge Acquisition in time window T^a (Essay Two)
(N = 2440 observations, 416 individuals)

Variable	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Intercept	2.22 *** (0.42)	0.52 (0.55)	1.94 *** (0.57)	1.51 * (0.78)	2.37 *** (0.51)	4.03 *** (0.69)
Research quality ^{b c}	0.27 * (0.11)	0.37 *** (0.11)	0.31 ** (0.11)	0.31 ** (0.11)	0.25 * (0.10)	0.26 * (0.10)
Research quantity ^{b c}	-1.92 *** (0.30)	-3.32 *** (0.58)	-1.87 ** (0.59)	-1.96 *** (0.60)	-3.12 *** (0.53)	-2.82 *** (0.53)
Experience ^b	0.03 ** (0.01)	0.03 *** (0.01)	0.05 *** (0.01)	0.04 *** (0.01)	0.04 *** (0.01)	0.05 *** (0.01)
Network size τ_{-1}^c	0.46 *** (0.08)	0.45 *** (0.08)	0.42 *** (0.08)	0.52 *** (0.15)	0.31 *** (0.07)	-0.10 (0.13)
Knowledge breadth ^b		1.80 ** (0.58)	-0.04 (0.59)		0.47 (0.52)	-0.39 (0.58)
Knowledge depth ^b		2.01 *** (0.23)	2.63 *** (0.24)	2.82 *** (0.32)	2.17 *** (0.21)	1.46 *** (0.29)
Knowledge depth squared ^b			-5.82 *** (0.54)	-5.82 *** (0.54)	-5.15 *** (0.48)	-5.13 *** (0.48)
New collaborative ties τ					0.04 *** (0.002)	0.05 *** (0.002)
Selection hazard				0.27 *** (0.33)		-1.03 *** (0.30)
Log likelihood	-7187.09	-7144.68	-7084.29	-7083.95	-6866.04	-6859.95

^a Standard errors are in parentheses. Individual dummies and cohort dummies were included but are not shown.

^b Cumulative scores until the year before the beginning year of time window T .

^c Logarithm

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

FIGURES

FIGURE 1

Population and Sample Frequency Distribution

FIGURE 2
The Moderating Effect of Past Productivity on the Relationship between Institutional Prestige and Internal Network Density

FIGURE 3
Summary of Hypotheses (Essay Two)

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