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Network stability, connectivity and innovation output

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ABSTRACT

With the patent co-inventing data of top 9 ICT firms with the highest patent application in China, this study establishes the co-inventing network and examines the moderate role of network connectivity, measured by classifying the individuals into two cohorts: inventors in the largest connected component and inventors in other isolated components. The network stability and innovation output demonstrate strong positive interaction, which is significant in not only the largest but also other isolated components. The clustering and centrality demonstrate significant effect on network stability and innovation output in the largest connected component, which is generally the same as that of extant studies. This impact is not significant in the other isolated components, which confirms the moderate role of network connectivity, i.e., fully connected networks constitute the basis for the network structure to be functioning. However, the significantly positive role of the structural hole is not moderated by the network connectivity. The contributions and implications of our findings is discussed at the end of this study.

1. Introduction

The effect of individual mobility on knowledge transfer, innovation, and competitive advantage is increasingly becoming an important domain of research (Gardner, 2005; Harris and Helfat, 1997; Rao and Drazin, 2002; Song et al., 2003; Sturman et al., 2008; Wezel et al., 2006). Interorganizational mobility of individuals affects gains or losses in terms of the competitive advantage and performance outcomes (e.g., survival, profitability, effectiveness in head-to-head competition) of organizations that lose individuals (Aime et al., 2010; Phillips, 2002). Therefore, most organizations are trying to curb the mobility and keep the stability of their employee groups, particularly the high-performers. Conversely, the employee's performance may also impact their stability. High-performers usually own high satisfaction with the current job, which makes them less likely to leave, while low-performers are more likely to seek outside opportunities. Although there are reciprocal effects (Shaw et al., 2005a), direct (Glebbeek and Bax, 2004) and indirect (Shaw et al., 2005b) evidence suggests that the effect of employee stability on his/her performance is stronger than the reverse, which may be the main cause that most extant studies focused on the former. However, extant studies did not clearly examine to what extent the reciprocal effect is ignorable. Since there is reciprocal effect, the causal analysis of employee stability and performance should take it into account from both empirical and theoretical perspectives. As the employee's performance and stability interact with and function on each other, this study will make a comprehensive examination of the bidirectional causalities, which is one of the main contributions of this study to extant literatures.

In the context of an organizational network, as the network becomes more connected, distance between any two nodes diminishes, it is possible that information can become more democratized (Ahuja et al., 2012), information can thereby diffuse more quickly, fostering outcomes such as innovation or creativity (Schilling, 2005; Schilling and Phelps, 2007). As the inventors' access to the information and knowledge is to a great extent dependent on the links with each other, the moderate effect of the network connectivity on the inventor stability and his/her performance is indispensable. Although the effect of network structure has been widely discussed by extant studies, e.g., Ahuja (2000), Nerkar and Paruchuri (2005), Paruchuri (2010), Cattani and Ferriani (2008), Zhang et al. (2014a), they are mostly based on the largest connected component within the whole network. As the disconnected components potentially conflate the influences of small-world structure and simple connection (Fleming et al., 2007) and usually take a relatively small ratio compared with the largest component (Casper, 2007), most studies focused on the largest component, while ignored the methods to develop a weighted average across disconnected components proposed by Schilling and Phelps (2007). However, besides the largest component, other components, e.g., the second and third largest, usually own well structured fabric. These components may also exhibit significant network effect, as the links constitute the base for inventor communication. Inventors with key positions may also have advantages in accessing information, and thereby generate higher innovation output in other smaller components. The specific inventive process may lead to the disconnections,

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e.g., pharmaceutical researchers are usually assigned to several groups, which are making mutually independent researches; technicians embarking at two different projects within the same firm may also lead to two isolated components. Obviously, inventors in the largest component represent only part of the firm's inventive activity. As the inventors in other components may also be doing important researches, ignoring these components may lead to a bias of the empirical results. In this sense, the network effect on network stability and performance, particularly in the partly connected contexts, deserves a further study. We will compare the differences of the network effects in the fully connected networks with that in partly connected networks, which formulates another main contribution of this study.

Additionally, extant studies provided only evidences that network connectivity is beneficial by proving that a greater ratio of the largest connected component positively impact innovation, e.g., Fleming et al. (2007), Chen and Guan (2010), Zhang et al. (2014b). As the linkages between individuals are the basic element constituting the network, greater extent of connectivity may be the key for the network indicators, e.g., clustering coefficient, centrality, path length, to be functioning on innovation. However, the moderate role of connectivity is not carefully examined by extant studies and will be another main job of this study.

The remainder of this study is organized as follows: Section 2 presents the hypothesis; Section 3 presents the data and methods; Section 4 provides the empirical results; Section 5 discusses and Section 6 concludes.

2. Hypothesis

Because continuous interaction among members is seen as a valuable resource for organizations, turnover has been argued to deplete social capital by damaging firms' internal social fabric (Dess and Shaw, 2001; Shaw et al., 2005a). Kwon and Rupp (2013) found that turnover among individuals who occupy key structural and relational network positions could lead to significant loss of social capital within organizations, resulting in lower firm performance. Individual turnover has been viewed as problematic for firm performance, as individuals' participation in organizational activities has been regarded as a necessary condition for effective firm functioning (Kwon and Rupp, 2013), and the individuals with more work experience usually generate more productions. This may be one of the main causes that firms with higher employee stability usually have higher survival rate (Phillips, 2002; Wezel et al., 2006). However, this positive reciprocal effect may be attenuated by the network connectivity, which determines the access of information and knowledge. For the lack of information and communication, employees in an isolated network are more likely to leave, while employees in a connective network have easier access to heterogeneous team, which is more productive (Hamilton et al., 2012) and makes employees less likely to leave. This gives the following formal hypothesis:

H1. *The inventor's network stability positively interacts with his/her innovation performance, while this positive reciprocal effect will be attenuated by the disconnected network.*

The links described in social networks influence one's propensity to stay on their job perhaps through a process of job embeddedness (Holtom et al., 2008), e.g., key individuals usually hold advantageous network position, which bring greater job embeddedness and satisfactions that make them less likely to flow away (Holtom et al., 2008). The individual performance may also be affected by their network positions, which determine the facilitation of information and knowledge acquisition. It has been proved that certain network structure, e.g., medium level clustering and small worldliness, shorter path length would benefit innovation by facilitating the access of information and knowledge (Chen and Guan, 2010; Fleming et al., 2007; Zhang et al., 2014b); Individuals with more structure holes may have lower level innovation output (Ahuja, 2000). As Ahuja (2000) has noted that the optimal structure of the network to a great extent depends on the objectives of the network members, it is necessary to make a further study of the relationships between the innovation performance and network position. We discuss the network position from three measurements: clustering coefficient, structural hole and centrality, which are widely used and discussed by extant studies in measuring the network structures.

As the network is becoming more clustered, there is a decline in the formation of bridging new ties (Gulati et al., 2012). The social structure is further characterized by self-containment (Gulati et al., 2012), which makes inventors less likely to change the current state and thereby more likely to be reliant on the network. However, the innovation performance may be affected by the clustering quite differently. Most studies have confirmed a middle-level clustered network encourages, but an extremely low- or high-level clustered network discourages innovation, e.g., Uzzi and Spiro (2005), Chen and Guan (2010), Fowler (2005), and Guimera et al. (2005). The role of a more clustered network maybe two sided: on one hand, it may diffuse knowledge that improves innovation, and on the other hand, it may bring too much common or even negative information that hamper creativity (Chen and Guan, 2010). Hence we make the following hypotheses:

H2. *(a). The inventor's clustering coefficient positively correlates with his/her network stability.*

H2. *(b). There is an inverted* 'U'-shaped relationship between *inventor's clustering coefficient positively impacts his/her innovation performance.*

The structural holes are gaps in information flows between alters linked to the same ego but not linked to each other (Burt, 1992). A structural hole indicates that the people on either side of the hole have access to different flows of information (Hargadon and Sutton, 1997). Ego networks rich in structural holes imply access to mutually unconnected partners and, consequently, to many distinct information flows (Ahuja, 2000). Therefore, inventors rich in structural hole usually have higher position, which makes them less likely to flow out. However, the effect of structural hole on innovation performance appears to be two sided: on one hand, inventors with extensive relations can foster the development of shared norms of behavior and explicit knowledge-sharing routines (Ahuja, 2000; Dyer and Noboeka, 2000; Uzzi, 1997; Walker et al., 1997), which enhances the innovation performance; on the other hand, the opportunistic actions of the inventor who hold the structural hole is greater, as his/her partners are not directly linked to each other (Ahuja, 2000). The contradictory effects may lead to two opposing point of views, one of which is selected for proposing hypothesis:

H3. *(a). The inventor's ego network rich in structural hole positively correlates with his/her network stability.*

H3. *(b). The inventor's ego network rich in structural hole positively impacts his/her innovation performance.*

Network centrality is a commonly used indicator of brokerage within social networks (Casper, 2007; Wassermann and Faust, 1994). The centrality is measured with three main indicators: betweenness, closeness and degree centrality, which function on the innovation from different aspects but finally show similar effect. Researches support a link between inventors performance and both number of ties and centrality in networks, with higher performing inventors holding more ties and having more network centrality (Burt, 1992; Cross and Cummings, 2004). Additionally, similar with the role of structural hole, researchers also believe that inventors with greater centrality will have access to more information, have more power and greater influence (Chen and Guan, 2010). Therefore, the centrality is more likely to show positive effect on network stability from the perspective of job embeddedness. The following hypotheses are accordingly proposed:

H4. *(a). The inventor's network centrality positively correlates with his/her network stability.*