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Knowledge creation in collaboration networks: Effects of tie configuration

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ABSTRACT

This paper studies the relationship between egocentric collaboration networks and knowledge creation at the individual level. For egocentric networks we focus on the characteristics of tie strength and tie configuration, and knowledge creation is assessed by the number of citations. Using a panel of 1042 American scientists in five disciplines and fixed effects models, we found an inverted *U*-shaped relationship between network average tie strength and citation impact, because an increase in tie strength on the one hand facilitates the collaborative knowledge creation process and on the other hand decreases cognitive diversity. In addition, when the network average tie strength is high, a more skewed network performs better because it still has a "healthy" mixture of weak and strong ties and a balance between exploration and exploitation. Furthermore, the tie strength skewness moderates the effect of network average tie strength: both the initial positive effect and the later negative effect of an increase in tie strength are smaller in a more skewed network than in a less skewed one.

1. Introduction

In history, scientists were often depicted as lonely wolves, and prominent discoveries were often credited to solitary authors. However, the production of science is increasingly collaborative (Adams et al., 2005; Hicks and Katz, 1996; Price, 1986; Wuchty et al., 2007). By pooling together different expertise and perspectives, collaboration contributes to cross-fertilization of ideas and enables combining different pieces of knowledge to create something novel and useful (Katz and Martin, 1997; Melin, 2000; Page, 2007). The prevalence of collaboration in science has driven science studies to expand from lab benches to collaborative settings at a larger scale (Chompalov et al., 2002; Cummings and Kiesler, 2005; Finholt and Olson, 1997; Shrum et al., 2001) and sparked vigorous studies of collaborative teams (Cummings et al., 2013; Hemlin et al., 2013; Lee et al., 2015; Levine and Moreland, 2004; Murayama et al., 2015; Walsh and Lee, 2015) and networks (Börner et al., 2004; Guimera et al., 2005; Newman, 2004; Sun et al., 2013) in science.

This study investigates the relationship between collaboration networks and knowledge creation at the individual level. Dynamic egocentric collaboration networks are viewed as the venue where scientific knowledge is produced, and the characteristics of egocentric networks shape the process of knowledge creation within the network, which in turn affects the impact or usefulness of the knowledge created from the network. At a fundamental level, knowledge resides within and is created by individuals (Nonaka, 1994). However, the creation of knowledge is also a social process (Latour and Woolgar, 1986; Nonaka, 1994). Therefore, it is important to place a creative individual within a network of interpersonal relationships for a better understanding of knowledge creation (Simonton, 1984). Previous studies have extensively investigated the effect of collaboration networks on research performance at the individual level (Abbasi et al., 2011; Gonzalez-Brambila et al., 2013; Li et al., 2013; McFadyen and Cannella, 2004; McFadyen et al., 2009). These studies typically adopt a *social capital* perspective, where a scientist's egocentric network or his/her position in the global network represents his/her social capital, and social capital affects research performance indirectly, through serving as an input for current knowledge creation. However, this paper studies collaboration networks as organizations of knowledge creation and focuses on how the current network affects knowledge creation directly, via its effect on the creative process and resource mobilization. Specifically, this paper focuses on the effect of tie strength and tie configuration on citation impact at the individual level.

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This paper makes the following theoretical contributions. First, it adds to the organization of science literature, studying egocentric collaboration networks as organizations for science production. Second, it explores tie configuration within collaboration networks and contributes to the development of a network theory beyond a simple dichotomy between strong and weak ties.

The rest of the paper is organized as follows. First, we briefly review the literature on collaborative teams and networks in science and discuss the motivation for studying egocentric networks. Second, we develop hypotheses concerning the effect of tie strength and tie configuration on knowledge creation, drawing literature of science studies, social networks, organization theory, and organizational behavior. We use a panel dataset with both survey and bibliometric information for 1042 American scientists in five disciplines (biology, chemistry, computer science, earth and atmospheric sciences, and electrical engineering). We incorporate (1) individual fixed effects to account for unobserved time invariant individual heterogeneity and (2) career age and prior performance to control for time variant individual differences. We found (1) an inverted *U*-shaped relationship between network average tie strength and citation impact, (2) a positive effect of the skewness of tie strength distribution on citation impact, when the network average tie strength is high, and (3) that the effect of network average tie strength is moderated by the level of skewness. We also discuss the implications of these findings.

2. Knowledge creation in science

2.1. Collaborative science: teams and networks

Scientific knowledge is increasingly created collaboratively, as reflected in the rising share of coauthored papers and the growing size of collaborative teams (Adams et al., 2005; Hicks and Katz, 1996; Price, 1986; Wuchty et al., 2007). While earlier science studies focus on individual traits and laboratory settings (Latour and Woolgar, 1986; Simonton, 1999; Zuckerman, 1967), the prevalence of collaboration in science calls for studying the organization of collaborative science, and researchers have extended science studies and laboratory ethnographies from lab benches to collaborative settings at a larger scale (Chompalov et al., 2002; Cummings and Kiesler, 2005; Finholt and Olson, 1997; Shrum et al., 2001).

Recently, there emerges a new body of literature labeled as *science of team science*, which brings in insights from the psychology literature on small groups and the sociology literature on work organizations to study the team production of science (Falk-Krzesinski et al., 2010; Fiore, 2008; Stokols et al., 2008). For example, previous research has investigated the group process (Levine and Moreland, 2004), leadership (Hemlin et al., 2013), and bureaucratization (Walsh and Lee, 2015) in scientific teams, as well as the effects of team characteristics on team productivity (Cummings et al., 2013), creativity (Lee et al., 2015), and the quality of team product (Murayama et al., 2015).

Besides scientific teams, collaboration networks have also been extensively studied at the system level (i.e., all sciences or a particular scientific field), covering topics such as patterns of collaboration networks (Guimera et al., 2005; Newman, 2004), evolution of scientific networks and mechanisms underlying the process (Börner et al., 2004; Sun et al., 2013), and the network effects on research performance (Guimera et al., 2005).

2.2. Individuals and egocentric networks

At the individual level, egocentric network or individual's position in the global network have also been explored to explain the productivity or creativity of individual scientists (Abbasi et al., 2011; Klenk et al., 2010; Li et al., 2013; McFadyen and Cannella, 2004; McFadyen et al., 2009). The individual-level network studies typically adopt a *social capital* perspective; a scientist's egocentric network or position in the global network represents his/her social capital, which in turn affects his/her performance the same way as intellectual and other capital. From this social capital perspective, collaboration networks affect individual performance indirectly through providing social capital as an input but not directly by serving as a work organization. This nuance is more evident when scrutinizing empirical strategies adopted in these studies, which measure social capital based on collaboration networks in previous years and estimate its effect on individual performance in the current year (McFadyen and Cannella, 2004; McFadyen et al., 2009). Preceding network provides social capital as an input for current knowledge creation, but the current network, which is directly responsible for the current science production, is ignored. Furthermore, focusing on the previous but not the current network does not explain how social capital is mobilized for current knowledge creation (Lin, 1999, 2001). Different from the social capital perspective, this paper studies the current collaboration networks as work organizations bearing direct effects on current knowledge creation.

The concept of social capital is evoked as a bridge between egocentric networks and individual performance, presumably because individuals or egocentric networks are not recognized as legitimate forms of organization for scientific production, while teams are. Accordingly, the distinction between our egocentric network approach and the team approach is twofold: in the egocentric network approach, (1) individual is still a relevant unit of analysis for studying knowledge creation in science and (2) egocentric collaboration network is also a legitimate form of organization for knowledge creation.

Science is increasingly performed in teams. However, at a fundamental level, knowledge still resides within and is created by individuals (Nonaka, 1994). Studies of group creativity also emphasize the importance of individuals' abilities, previous experiences, and other resources that they carry with them (Amabile, 1983; Ford, 1996; Woodman et al., 1993). Therefore, research evaluation at the individual level is still a relevant practice, and a scientist endowed with a higher level of intellectual or social capital can contribute his advantages to all his collaborative teams and achieve better performance across all his collaborations.

In addition, although science is increasingly performed in teams, knowledge creation within a team also depends on activities outside the team. One distinct feature of modern science, compared with other systems of work organization, is its autonomy and self-governance (Whitley, 2000). As a result, scientific teams are extremely fluid, with ill-defined and constantly changing boundaries (Borgman, 2007). This fluidness of scientific teams is also reflected in the difficulty of determining authorships (Haeussler and Sauermann, 2013; Laudel, 2002). More importantly, the fluidness of collaborative teams is associated with the interdependence between teams connected by common members. Scientists often participate in multiple teams simultaneously, and these teams may share several common members and also similar research agendas. Under such circumstance, knowledge spillovers across teams are likely to take place. For example, Tang and Hu (2013) showed that scholars pick up new research lines from their international collaborators and further pursue them in their domestic collaborations, and Wang and Hicks (2015) demonstrated knowledge spillovers from a scientist's new collaborators to his/her other teams not involving these new collaborators. Since knowledge creation at the team level also depends on external activities, it is also important to study the open and dynamic egocentric networks, in addition to the closed collaborative teams, in order to better understand knowledge creation in science.