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Alliance network configurations and the co-evolution of firms' technology profiles: An analysis of the biopharmaceutical industry

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ABSTRACT

Many inter-organizational networks exhibit *small-world* properties in that they consist of close-knit sub-networks or blocks, along with sparse ties spanning those blocks, so that an average firm in the network has short connections to a wide range of partners. While extant literature has shown that networks exhibiting these properties outperform those that do not, little empirical research exists on the process of knowledge exchanges among firms within and across blocks in a network. This paper aims to fill this gap in the context of inter-firm technology alliance networks in the biopharmaceutical industry. Adopting an intertemporal perspective, we examine how particular alliance relationships within a network affect learning and information flows and therefore the co-evolution and similarity of the firms' technology profiles. Results of a Quasi-Maximum Likelihood analysis on a 10-year panel data set consisting of 217 firms reveal that firms in blocks tend to develop similar technology profiles over time. The results further demonstrate that firms located closer to each other in a network (shorter path length) display higher levels of resemblance compared with firms that are farther apart. However, perhaps more importantly and contrary to expectations, our results also show that the length of ties between two firms has a smaller effect on the similarity between their profiles when firms are not members of the same block.

1. Introduction

Organizational scholars have long explored the characteristics of interorganizational networks and their effects on, among other things, the durability of collaborations, the efficiency of knowledge exchange, and the performance of firms (Burt, 1992; Coleman, 1988; Ahuja, 2000b; Sytch and Tatarynowicz, 2014). Among the wide variety of network characteristics that have been examined, a key focus has been on structural and relational embeddedness (Granovetter, 1992; Nahapiet and Ghoshal, 1998; Gargiulo and Benassi, 2000; Inkpen and Tsang, 2005).

Structural embeddedness refers to the extent to which a firm's alliance activity is integrated in the social context of a close-knit sub-network or block to which the firm and its partners belong. An alliance block is a highly cohesive subset of actors in a network wherein norms are easily diffused and firms develop shared mental models (Knoke and Kuklinski, 1982; Nahapiet and Ghoshal, 1998; Baum et al., 2003). Block affiliation therefore facilitates information exchanges that are often mutually reinforcing, leading to a fine-grained understanding of the ideas and knowledge exchanged within the block (Coleman, 1988; Krackhardt and Hanson, 1993; Ahuja, 2000b; Uzzi, 1997).

Relational embeddedness, on the other hand, reflects the cohesiveness of ties between partner firms in a dyad, irrespective of whether they belong to the same block or not (Granovetter, 1992; Nahapiet and Ghoshal, 1998; Hoang and Rothaermel, 2005). Of particular import are sparse, block-spanning collaborative ties associated with firms that occupy structural holes between blocks. Such a strategic positioning between blocks allows these firms to exert control over their exchange partners in multiple blocks and thereby elicit novel information from them (Burt, 1992, 2004; Gulati, 1999; Ahuja, 2000a). Whereas block affiliation affords the safety of reliable partners and contributes primarily to strengthening firms' core competencies, ties that span a firm's block expose it to novel knowledge elements. Cultivating strong relational links with firms outside a firm's own block therefore assumes much significance for firms in their network strategy.

Consistent with the notion of a *small world* (White, 1970; Watts, 1999), several studies have shown that most real-world networks are characterized by a combination of dense ties in local blocks and sparse block-spanning ties (Kogut and Walker, 2001; Uzzi and Spiro, 2005;

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Baum et al., 2003; Verspagen and Duysters, 2004).[1] Given the growing significance of technology-related inter-firm relationships for the "technological core" of companies (Chesbrough, 2003), it is important to understand the effect of various forms of embeddedness on knowledge flows and mutual learning. Nevertheless, this issue has not been empirically explored in the literature, with much of the prior research focusing instead on the effect of particular network configurations on the stability of alliances (Kogut, 1989; Park and Ungson, 2001; Polidoro et al., 2011) or on performance (Sytch and Tatarynowicz, 2014; Dong and Yang, 2016; Rowley et al., 2000; Gilsing et al., 2008; Baum et al., 2000; Zollo et al., 2002; Koka and Prescott, 2008; Padula, 2008; Mahmood et al., 2011). Highlighting this deficiency in extant research, recent studies (see for, example, Ahuja et al., 2012; Stolwijk et al., 2013) have called for examining, in particular, the dynamics of network evolution and its effects on knowledge development.

This paper responds to these calls by examining how various network configurations shape learning and knowledge exchanges between firms and therefore influence the extent to which the technology profiles of firms in inter-firm networks co-evolve over time. Specifically, the paper investigates (1) the effect of block affiliation and relational proximity (fewer intermediaries) between firms in the inter-firm network on the co-evolution of their technology profiles, and (2) whether the effect of proximity is less salient when firms belong to the same block. This exercise is one of the first attempts to uncover the effect of different network configurations on the efficiency of information exchange and learning. We carried out our analysis on a unique data set of 217 biopharmaceutical companies that engaged in about 800 technology alliances over a period of 10 years. The following section provides the theoretical background of the study and develops the hypotheses. The data, variables, and methods are described in Section 3. In Section 4 we discuss the results and the final section highlights the theoretical and managerial contributions of the study.

2. Background and Hypotheses

2.1. The interplay between inter-block and intra-block alliances

Network scholars have long wrestled with the challenge of identifying the ideal network configuration. A key question has been whether it pays more for a firm to engage in ties in a dense, cohesive block or to occupy structural hole positions that exist between blocks by establishing sparse block-spanning ties (Rowley et al., 2000; Gilsing et al., 2008; Baum et al., 2003; Koka and Prescott, 2008). In the former conceptualization, known as the closure argument, repeated interactions between firms in dense networks solidify trust and cooperation, resulting in intensive, efficient transmission of ideas (Coleman, 1988; Krackhardt and Hanson, 1993; Gulati, 1995b; Powell et al., 1996; Gulati, 1999; Ahuja, 2000b). Cohesive network structures that are highly interconnected act as reputation-building mechanisms in that information on deviant behavior is readily disseminated, ensuring that partners perform closer to one another's expectations. These networks thus facilitate the effective exchange, understanding, combination, and utilization of knowledge.

The other line of reasoning offers the so-called brokerage argument, which suggests that successful firms occupy the structural holes that exist between blocks and hence are uniquely positioned to access novel information (Burt, 1992, 1997; Hargadon and Sutton, 1997). Firms situated between blocks enjoy the benefits of experimenting with novel knowledge because they are exposed to a wider variety of knowledge from technologically distant partners (Padula, 2008). Such a process of exploration stimulates the creation of new knowledge and broadens a firm's knowledge base by enhancing its *reach* in terms of accessing diverse flows of knowledge. Furthermore, sparse network ties ensure that firms exercise greater *autonomy* vis-à-vis their partners and, therefore, have greater *control* over the resources being transmitted through these ties (Burt, 1997; Rodan, 2010).

In spite of the apparent contradiction between these two perspectives about what might be the best networking strategy for firms, there has been increasing consensus that links within a dense network and links to distant parts of the network are both important from a knowledge-sourcing perspective (Burt, 2000; Rowley et al., 2000). Given firms' need to pursue both the exploration of new technologies and the exploitation of existing knowledge bases (March, 1991), a dual network structure made up of frequent, routinized interactions in a cohesive network and access to sparse networks would be the normative ideal situation for innovation (Moran, 2005; Padula, 2008). Indeed, most networks are characterized by the presence of dense within-block ties and sparse block-spanning ties, confirming the properties of a small world which symbolizes an efficient network configuration (Uzzi et al., 2007; Schilling and Phelps, 2007; Watts, 1999; Baum et al., 2003; Padula, 2008).

The specific nature of ties within and between blocks imply that the information content and intensity of the knowledge exchanges associated with these ties are different, leading to different patterns of (co) evolution of technology profiles of firms connected to each other within a block versus those connected between blocks. A firm's technology profile captures the distribution of its technological strengths across multiple technology fields (e.g. Patel and Pavitt, 1997; Sampson, 2007). The changes in its technology profile with respect to that of another firm, therefore, provide a good indication of the similarity or differences in technological learning between the two firms. The degree of similarity between two technological profiles is commonly referred to as technological distance (Gilsing et al., 2008). Therefore we will use this term throughout the hypotheses section to indicate the degree of similarity between two technological profiles. In the following, we discuss how particular network characteristics like membership in the same block and proximity of ties between firms (captured through the path length of ties), as well as the inter-relationship between these two, may shape knowledge exchanges and, ultimately, the co-evolution of firms' technology profiles in a network.

2.2. Hypotheses

2.2.1. Block membership and the evolving technological distance between firms

The social structure of inter-firm collaborative relationships in dense blocks is characterized by mutual trust and enduring relationships that facilitate smooth exchange of ideas (Uzzi, 1997; Walker et al., 1997; Gulati and Gargiulo, 1999). In such blocks, firms usually focus on incremental innovations (Rosenkopf and Nerkar, 2001) and engage in local search for knowledge that does not conflict with their existing mental models (Nelson and Winter, 1982). Cohesive networks create collaboration routines suitable for the efficient exchange of similar knowledge and skills that augment firms' existing capabilities (Mowery et al., 1996; Kogut, 1988). Firms are thus able to specialize in their existing core technology base (March, 1991) and further improve and deepen it. In the process, they will typically need to exchange highly sensitive technological knowledge related to their core products and markets. A high degree of trust is thus required to limit unwanted leakages and minimize the risk of free ridership (Gilsing and Nooteboom, 2005). Frequent interactions help build trust and intimacy and, over time, lead to the creation of solid, reciprocal ties (Granovetter, 1973; Brass et al., 1998). Since firms invest a substantial amount of time and energy in establishing these strong relationships, it is highly unlikely that they will change partners in the short run, because this would involve substantial switching costs (Chung et al.,

[1] Formally, small-world networks are those networks that exhibit high cliquishness or clustering in that an average actor's partners are also likely to be connected to one another, while at the same time, the average number of intermediaries needed to connect any two actors—that is, the average path length—is relatively low (Uzzi et al., 2007; Schilling and Phelps, 2007).