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Network embeddedness and the exploration of novel technologies: Technological distance, betweenness centrality and density

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ABSTRACT

This paper aims to understand better the innovation potential of a firm's alliance network. Here we analyze the role of an alliance network in terms of the technological distance between partners, a firm's network position (centrality) and total network density. We study how these three elements of an alliance network, separately and in combination, affect the 'twin tasks' in exploration, namely novelty creation on the one hand and its efficient absorption on the other hand. For an empirical test, we study technology-based alliance networks in the pharmaceutical, chemical and automotive industries. Our findings indicate that successful exploration indeed seems to require a delicate balance between these two exploration tasks. A second conclusion is that different network positions yield different pay-offs in terms of the number of explorative patents. In other words, success rates for exploration are not spread equally across firms. However, position alone does not tell the full story. Our empirical findings clearly indicate that exploration success also depends on the other two dimensions of embeddedness, namely technological distance and network density. The three elements of network embeddedness need to be considered jointly in order to understand their complementary effects on both novelty creation and absorptive capacity.

1. Introduction

There is now increasing consensus in the academic literature that a firm's embeddedness in a network of interfirm relations matters for its economic and innovative performance (Nooteboom, 1992; Hagedoorn, 1993; Powell et al., 1996; Rowley et al., 2000; Ahuja, 2000a; Owen-Smith and Powell, 2004). The empirical evidence has indicated that this relationship between embeddedness and innovation can be found in industries as diverse as chemicals (Ahuja, 2000a), biotechnology (Baum et al., 2000; Powell et al., 1996), semiconductors (Stuart, 1998), textiles (Uzzi, 1997), personal computers (Hagedoorn and Duysters, 2002) and banking (Zaheer and Bell, 2005). More recently, some studies have started to unravel this notion of embeddedness in order to understand in what specific ways it contributes to a firm's innovation performance. Here, characteristics of partners have been studied such as their degree of innovativeness (Stuart, 1998) as well as the properties of alliances such as the role of formal governance mechanisms (Mowery et al., 1996), equity vs. non-equity alliances (Rowley et al., 2000) or the role of repeated contacts (Wuyts et al., 2005). Beyond the dyad level, studies at the network level have shown that the properties of an alliance network also affect innovation. Here it has been shown that apart from the number of direct ties (Ahuja, 2000a; Shan

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et al., 1994) also a firm's indirect ties (Ahuja, 2000b) and the redundancy among these ties (Ahuja, 2000b; Baum et al., 2000; McEvily and Zaheer, 1999) affect its innovation performance.

In most of these studies an important function of alliances is that they function as 'pipelines' through which information and knowledge flows between firms (Owen-Smith and Powell, 2004). This focus on the diffusion potential of alliances may not be surprising as most studies on the role of embeddedness have been assuming conditions of relative environmental stability. Here, embeddedness refers to routinisation and stabilization of linkages among members as a result of a history of exchanges and relations within a group or community (Gulati, 1998). Under such structure-reinforcing conditions, the role of embeddedness is increasingly well understood (Gulati, 1998; Madhavan et al., 1998; Koka et al., 2006). These conditions connect with March's category of exploitation (1991) in which environmental uncertainty is rather limited and the focus is on the refinement and extension of existing competences and technologies. The rationale for teaming up with partners then is formed by possibilities to obtain complementary know-how (Teece, 1986) and/or to speed up the R&D process in industries where time-to-market is crucial. Here, cooperation is attractive as partners have a good understanding of the relevant issues at hand and alliances enable a rapid diffusion of knowledge among partners, enhancing the efficiency and speed of cooperation (Gilsing, 2005).

In this strand of literature, an implicit underlying assumption is that similarity of partners is beneficial for learning and innovation. This follows from Cohen and Levinthal's (1990) influential notion of absorptive capacity, where the idea that the extent to which firms can learn from external knowledge may be largely dependent upon the similarity of the partners' knowledge bases. In a similar vein, different studies have demonstrated that learning potential declines with an increase in dissimilarity of knowledge stocks (Hamel, 1991; Lane and Lubatkin, 1998; Mowery et al., 1996; Fleming and Sorenson, 2001). So, for inter-organisational learning in exploitation, similarity is attractive and distances in knowledge and cognition (cognitive distance) constitute a liability.

This raises the question of how to understand the role of network embeddedness in view of exploration that can be characterized by breaking away from the established way of doing things, with a focus on the discovery and experimentation of new technologies (March, 1991; Nooteboom, 2000). By its very nature, exploration is not about efficiency of current activities, but rather forms an uncertain process that deals with the search for new, technology-based business opportunities (Rowley et al., 2000; Nooteboom, 2000), requiring the production of new insights and knowledge. This points to a different role of a firm's alliance network, namely its recombination potential for *new* knowledge creation rather than its function as a channel for diffusion of *existing* information and knowledge for exploitation. Existing literature has largely ignored this role of alliances for novelty creation and is therefore unable to explain the development of new knowledge and competencies (Hagedoorn et al., 2000; Phelps, 2005). In contrast to exploitation, in this process of exploration partner similarity is unattractive whereas cognitive distance between partners forms an important asset.

The main aim of this paper is to develop an understanding of the role of a firm's alliance network in view of exploration. To do so, we will first consider this role of cognitive distance between firms in order to understand how far dissimilarity between partners is attractive in view of exploration. Second, we combine such a cognitive view with a social structural one. In this way we complement the literature that has predominantly focused on the role of economic and social factors regarding alliance formation and the role of network embeddedness (Gulati, 1998). A cognition-based understanding of these processes, however, is still in its infancy (Moran, 2005).

Combining the role of cognitive and social structural factors may provide us with new insights into what constitutes an optimal network structure for exploration. As we will argue, for exploration firms are faced with a dual task. On the one hand, they need to develop access to heterogeneous sources of knowledge and in this way create a potential for novel combinations. This requires an emphasis on diversity and disintegrated network structures, which is related to Burt's argument (1992) stressing the benefits of access to non-redundant contacts to obtain novel information (novelty value).

On the other hand, firms need to make sure that such novel knowledge, once accessed, is evaluated, and when proven to be valuable is adequately absorbed. This process favours more homogeneous network structures in view of integrating the diverse inputs obtained from distant partners (Hansen, 1999). This is more in line with Coleman's view (1988) stressing the benefits of redundant network structures. Given these differences between the two tasks, we claim that a firm's network will impact differently on each task. So, an important contribution of this paper is that it investigates how far optimal embeddedness for novelty creation may form a burden for absorptive capacity and vice versa. In this way, we may shed new light on the ongoing debate on the validity of the arguments by Burt, favouring structural holes, versus those of Coleman, favouring closure.

This paper is structured as follows. In Section 2 we elaborate our theoretical argument and formulate a number of hypotheses. Then, in Section 3, we present details about the data, the specification of variables, and the estimation method. In Section 4 we present our main findings. Finally, in Section 5, we provide a discussion of the results, the main conclusions and some indications for further research.

2. Theory and hypotheses

As argued above, the central focus of this paper is on the role of a firm's alliance network regarding the 'twin tasks' of on the one hand creating novel combinations, and on the other hand the build-up of absorptive capacity for understanding such novel combinations. To understand its role, we study a firm's alliance network along three dimensions. First, following Nooteboom et al. (2005), we consider the role of cognitive distance among the firms making up such an alliance network. Here, cognitive distance refers to the