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Innovation and network multiplexity: R&D and the concurrent effects of two collaboration networks in an emerging economy

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ABSTRACT

This study focuses on the multiplexity of firm R&D networks, and it investigates two types of boundary-spanning networks: the bipartite network between firms and government-sponsored institutions (GSIs), and the traditional firm–firm network. We apply a social network perspective to examine the effects that these kinds of networks have on firm innovativeness, in relation to the effects of the firm's internal R&D efforts. We define the firm–GSI network as bipartite, and we investigate how the structural characteristics of this network (cohesion and centrality) affect innovativeness. We then decompose the innovational effects of firm–firm networks into two categories (intra- and inter-sector) to distinguish the effects of these collaboration networks. Furthermore, we investigate how these various external collaborative networks interact with a firm's internal R&D efforts for driving innovativeness. Our empirical study of 420 manufacturing firms in Mexico evaluates evidence from surveys and secondary data. The findings indicate that the structural properties of both firm–GSI and firm–firm networks have positive effects on innovativeness, but firm–GSI network cohesion has a stronger negative interaction with R&D in influencing firm innovativeness. Moreover, intra-sector centrality in a firm–firm network has a stronger negative interaction with R&D than inter-sector centrality does in driving firm innovativeness. We contribute to the literature by integrating insights from the perspectives of network multiplexity, social embeddedness, and resource complementarity in regard to inter-organizational behavior. Our study also provides meaningful guidelines for both managers and policy makers. The study's findings are robust to concerns of common method bias and alternative model specifications.

1. Introduction

Innovation strategy research has increasingly recognized that effective boundary spanning of a firm's knowledge sources is central to a successful innovation strategy, and that a combination of internal R&D and acquisition of external knowledge is vital for the success of strategic innovation (Chesbrough, 2006; Love et al., 2014; Veugelers and Cassiman, 1999). Accordingly, recent models of innovation have shown that firms are increasingly “opening” up their R&D borders through various types of collaboration networks (Ahuja, 2000b; Aral and Van Alstyne, 2011; Tortoriello et al., 2014). In addition to developing firm–firm research collaborations, firms may seek to collaborate with government sponsored institutions (GSI) for the external knowledge needed to create new products, processes, and technologies (Carnabuci and Operti, 2013). This trend is especially salient and critical for small and medium enterprises (SMEs) in emerging economies, due to their relatively limited resources and capacities for innovation (Baumann

and Kritikos, 2016; Lee et al., 2001). As firms seek to systematically open up their R&D borders, one of the challenging tasks for managers is to balance their activities between external and internal R&D. For policy makers, it has grown increasingly important to design effective public support for R&D investment through GSI–firm collaboration. These policy makers also aim to help the recipients achieve an optimal configuration that maximizes the benefits of input resources.

At the heart of this challenge lies the problem of how internal R&D interacts with external research activities. Some literature has offered analyses regarding the competing effects of complementarity and substitutability. To date, however, such analyses have yielded contradictory sets of empirical evidence. One stream of research has indicated that internal and external R&D efforts are complementary activities, which jointly improve a firm's innovativeness (Cassiman and Veugelers, 2006; Lokshin et al., 2008; Rothaermel and Hess, 2007; Schmiedeberg, 2008). A number of other studies have indicated that the relationships between internal and external sources of innovation are non-

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complementary, or even substitutionary (Hess and Rothaermel, 2011; Laursen and Salter, 2006). These mixed findings push both scholars and practitioners to achieve a more profound and systematic understanding regarding the joint effects that external and internal R&D efforts have on a firm's performance in terms of innovation. In considering the boundary expansions of a firm's knowledge sources and resource networks, it is clearly useful to take a multiplex network perspective for exploring the innovation impact of external R&D efforts on innovation. This approach is helpful because it is important to differentiate between the effects that firm-GSI collaborations and firm-firm research collaborations have on firm innovativeness, as these types of collaborative networks are different in nature. We address three research gaps to advance the literature, and we provide guidance for both firm executives and policy makers.

The first gap relates to firm–GSI research alliances. Studies have investigated knowledge-transfer alliances (Bellucci and Pennacchio, 2016; Lakpetch and Lorsuwanarat, 2012) and have identified certain success-related factors (Mindruta, 2013; Schofield, 2013; Steinmo, 2015), but this line of research has failed to offer a definite conclusion regarding the impact of such alliances on firm innovation. Overall, research has suggested that government-sponsored innovation programs may be effective in achieving economic and social goals (Hsu et al., 2009; Wei and Liu, 2015). However, the magnitude of this effect varies with firm characteristics (Stuart et al., 2007), orientation towards innovation (Bellucci and Pennacchio, 2016), and industry-related factors (Lakpetch and Lorsuwanarat, 2012). Several researchers have found that government-sponsored programs often have insignificant (Hsu et al., 2009; Wu et al., 2006) or even negative effects on firm innovation (Broekel, 2015; Yu et al., 2016). These negative effects may arise due to discrepancies between the partners' objectives (Fontana et al., 2006), limitations in human resources (Jung and Andrew, 2014), or the crowding of internal R&D input (Yu et al., 2016).

Despite the significance of this topic, the causes for these discrepancies in findings have not yet been clarified. Therefore, we propose a unique social network approach for capturing the structural nature of such firm-GSI networks. In these networks, direct links to guide the free flow of information, knowledge, and resources from GSIs to firms are likely to exist only as bipartite ties between the GSIs and the participating firms. Such bipartite networks are distinct from the more traditional ego-networks of research alliances between various firms. Thus, it is relevant to examine the innovation-related outcomes of various types of collaborative firm relationships from a network multiplexity perspective. Advantageous positions in a collaborative network (in terms of centrality or cohesion) can enhance the prominence of a firm and the benefits from information and knowledge that it can obtain within its network (Guler and Nerkar, 2012; Larcker et al., 2013). Bipartite network cohesion fosters knowledge spillovers and recombination among the bipartite network members due to the members' active engagement, and to their circulation and effective application of quality information (Guler and Nerkar, 2012). In comparison, bipartite network centrality benefits firms primarily in terms of access to information and knowledge (Gulati, 1995; Lee et al., 2015), transmission of processes and norms (Mahmood et al., 2011), and legitimacy signals (Lin et al., 2009).

The second gap is related to firm–firm alliances. Studies of firm–firm alliances have predominantly used aggregated measures to examine network structures, and these studies have treated all of the firm–firm interactions within a collaborative network as the same (Carnabuci and Operti, 2013). However, firms may establish collaborative relationships with partners within their own sector, or with partners across different sectors. Although these relationships may influence innovation via similar mechanisms, such as increased access to resources and knowledge spillovers (Jensen and Roy, 2008; Mitchell and Singh, 1996), the effects that intra- and inter-sector collaborations have on firm innovativeness may differ, due to the distinct nature of the shared resources. Basically, similar types of knowledge are exchanged between firms that are in the

same network communities (industries) (Burt, 1992). Specifically, intra-sector collaboration offers more advantages in terms of knowledge assimilation and recombination, due to the greater within sector similarity of product lines, technologies, operating procedures, business norms, managerial routines, and the generally enhanced absorptive capacity between firms in the same sector (Cohen and Levinthal, 1990).

We bridge the first and second gap to address the third gap, which is related to the interplay between internal and external R&D activities. The diversified resources and knowledge that firms acquire externally may interact with the resources and capabilities they develop internally through investment and strategic management (Lin et al., 2009). The complementarity (or substitution) between external and internal knowledge and resources significantly influences a firm's decision to optimize its resource allocation between various R&D activities (Arora and Gambardella, 1990; Das and Teng, 2000). Firm's internal R&D efforts positively affect firm innovation primarily by contributing to more efficient utilization of the available financial and human resources through accessing, modifying, exploring, and generating new technologies (Hoffman et al., 1998). Based on the above analyses and due to the same boost of internalization and recombination of acquired resources and knowledge, a stronger negative interaction effect may arise between firm-GSI cohesion and firm R&D, than the effect which arises between firm-GSI bipartite centrality and firm R&D. Similarly, a stronger negative interaction effect is more likely to happen in the interplay between centrality in an intra-sector alliance and a firm's own R&D efforts, than it is to happen in the interplay between centrality in an inter-sector alliance network and a firm's R&D.

By taking a network embeddedness and network multiplexity perspective, our study aims to make several contributions to the literature on cooperative research networks and firm innovation. First, we characterize the two widely adopted but distinct forms of collaborative networks (the bipartite firm-GSI network and the regular firm-firm collaborative network), and we develop an integrated framework for investigating their effects on innovation. Second, we extend our understanding of firm-GSI collaboration by differentiating between the effects that various structural characteristics of these networks (i.e., bipartite network cohesion and bipartite network centrality) have on firm innovativeness. Third, we advance knowledge in this area by decomposing the intra- and inter-sector effects that firm-firm alliance networks have on firm innovativeness. Fourth, we theorize the interplay between firms' efforts in pursuing innovation through external collaboration, and their internal R&D efforts toward developing innovative products or manufacturing techniques. In summary, we answer the call to investigate the effects of multiplex networks, and of interactions between internal and external R&D activities. We conduct this investigation in the highly relevant context of SMEs operating in an emerging economy (e.g., Bao et al., 2012).

We operationalized this research by investigating the effects of collaborative networks on firm innovativeness among 420 manufacturing firms in Mexico. These firms were participants in the five key sectors of the Mexican economy: food, high technology, design, automobiles, and plastics. The results of this study provide managerial implications for firms seeking to collaborate with other firms and with GSIs. By demonstrating and interpreting the interaction effects between the firms' external collaboration strategies and their internal R&D efforts, our findings provide guidance to both managers and policymakers on how firms can optimize their strategies for internal and external knowledge acquisition, and how government R&D resources can best be allocated to promote greater innovation on SMEs.

2. Theoretical background and hypotheses development

The literature on innovation has commonly emphasized the importance of boundary expansion to enable firms to acquire the external knowledge and resources needed for enhanced innovation (Veugelers and Cassiman, 1999). Boundary expansion constitutes an "open

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