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Openness and innovation in the US: Collaboration form, idea generation and implementation

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ABSTRACT

Much current work in management of innovation argues that it is becoming increasingly necessary for inventors and their firms to exploit information and capabilities outside the firm in order to combine one's own resources with resources from the external environment. Building on this prior work, we examine the relationship between collaboration and innovation. Using detailed information on a sample of triadic patents, with over 1900 responses in the US, we report on the rates of collaboration of various forms, and test the effects of collaboration. Our results suggest that just over 10% of inventions involve an external co-inventor and about 23% involve external (non-co-inventor) collaborators (with 27% involving any external collaborators). We find evidence that heterogeneous collaboration and university-industry collaboration in inventing drive higher invention quality. However, vertical collaboration at the inventing stage is relatively more critical to commercialization at the implementation stage than is university-industry collaboration. These results suggest that the impact of different forms of collaborative innovation may vary depending on the stage of the innovation process.

1. Introduction

While individual inventors are key to technological progress, it is becoming increasingly necessary for inventors and their firms to exploit information and opportunities outside the firm in order to combine one's own capabilities and resources with those from the external environment (Dahlander and Gann, 2010). Open innovation allows firms to better exploit information and the complementary capabilities of external organizations (Chesbrough, 2003; Hayashi, 2003; Motohashi, 2005; Powell et al., 1996).

Building on the literature on innovation collaboration, this study examines rates of collaborative inventing in the US and the effects of research collaboration on innovative performance. Dahlander and Gann (2010) note that open innovation includes different forms of openness: openness in the inputs (for example, through in-licensing or collaborative R&D) and openness in the exploitation of the invention (for example, through out-licensing). In this paper, we are concentrating on openness in the inputs, especially, research collaboration, and test its effects on two different stages: idea generation (i.e., invention) and idea implementation (i.e., commercialization), following the Schumpeterian notion of innovation as a two-step process. In other words, we examine how openness in the inputs (i.e., information gained at the idea generation stage) not only affects the quality of the invention as a result of idea generation, but also has an impact on exploitation of the invention at the idea implementation stage.

The first stage, invention, involves the creation of a new, potentially useful technology. Therefore, invention is likely to benefit from broad information access. Moreover, firms' collaborations with universities will be important to obtain radical or novel knowledge and create high-value inventions. The second stage is commercialization, translating that invention into practice (i.e., innovation). Here, information obtained through firms' collaboration with suppliers or customers in the inventing stage may be more beneficial in commercializing the invention even after the collaboration is over (March, 1991).

In this paper, we contribute to developing a theory of the differential impact of collaboration across the two stages of the innovation process, examining collaboration patterns in the US. First, using original survey data providing project-level information on a large sample of inventions in the US, we describe openness in the inventing process. We then examine the effects of research collaboration, considering the heterogeneity of collaboration and different types of partnerships in the inventing stage, on invention quality (invention) and commercialization (innovation). By heterogeneity, we mean the span of information space covered by the

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collaboration, or, put differently, the distance in the information set of partners from that of the focal inventor's firm. The results show that heterogeneous collaborations, including university-industry (U-I) collaborations, are associated with higher quality inventions. Furthermore, we find that, net of quality, vertical collaborations (i.e., collaboration with suppliers or customers) in the inventing stage lead to greater likelihood of commercialization at the implementation stage. This shows the relative importance of different types of partnerships in inventing to the different stages of innovation. We finish with a discussion of the theoretical, policy and methodological implications of our findings.

2. Literature review and theory development on collaboration and innovation

Arguments about the potential benefits of collaborative innovation are grounded in the more fundamental literatures on evolutionary economics, cognitive psychology and network theories of innovation. Evolutionary economists argue that bounded, local search limits the ability of a firm to fully exploit potentially valuable information (Cohen and Levinthal, 1990; Nelson and Winter, 1982; Nooteboom, 2008). Evolutionary economics also contends that broadening the search can improve innovation performance (Nelson and Winter, 1982). Cognitive psychology and computer science models of problem solvers show that functional diversity in the problem solving team should increase team performance by allowing broader search (Ancona and Caldwell, 1992; Hong and Page, 2004; Pieterse et al., 2013). Similarly, network ties, such as R&D collaborations and alliances, can facilitate information flows and encourage innovation (Owen-Smith and Powell, 2004). Moreover, the literatures on transaction costs, strategic management and industrial organization have seen research partnership as an alternative, intermediate form falling between the market and the firm and as a means of increasing efficiency and synergy, accessing complementary assets and internalizing knowledge spillovers (Bougrain and Haudeville, 2002; Hagedoorn et al., 2000; Nooteboom, 2008; Powell, 1990). Even though collaboration studies are grounded in diverse theoretical literatures, they all agree on the importance of research collaboration for knowledge-seeking and knowledge-creation (Powell, 1998). The locus of innovation is not limited to individual firms, but found in networks of learning, which encourages specialization and cross-fertilization across participants and helps learning and transfer of tacit knowledge (Bougrain and Haudeville, 2002; Katz and Martin, 1997; Powell, 1998).

Although much of the theory on knowledge source diversity and inter-organizational collaboration is focused on how collaboration contributes to generating novel combination, seen as a precursor to valuable innovation, many collaboration studies use novelty of innovation (e.g. radical or incremental), impact (e.g. patent citations), or commercial value (e.g. sales from the innovation) as an outcome, collapsing the innovation process into its outcome to test the effects of collaboration (e.g., Bougrain and Haudeville, 2002; Hottenrott and Lopes-Bento, 2015; Katila and Ahuja, 2002; Laursen and Salter, 2006; Leiponen and Helfat, 2010). However, research collaboration or partnerships may have different effects on the different stages of the innovation process. For example, building on the Schumpeterian two-stage process and March's (1991) distinction between exploration and exploitation, Rothaermel and Deeds (2004) find that exploration alliances are associated with more invention, while exploitation alliances are associated with more innovation. Likewise, building on but extending these prior studies, in this section, we develop a testable theory of the relative effectiveness of collaboration in inventing on the different stages of the innovation process: idea generation (i.e. invention) and idea implementation (i.e. commercialization).

2.1. Effects of knowledge heterogeneity on invention quality and commercialization

There is substantial prior work discussing the advantages of collaboration for innovation (Chesbrough, 2003; Laursen and Salter, 2006; Owen-Smith and Powell, 2004). Laursen and Salter (2006) find that firms that draw from a broader range of information sources, and those that draw more deeply from those sources, are more innovative. Leiponen and Helfat (2010) and Love et al. (2013) argue that more linkages to external knowledge sources or a broader span of knowledge sources increase the probability of gaining useful knowledge leading to a more valuable innovation outcome, and knowledge obtained from different types of linkages increases the complementarity between external knowledge and internal capability. Prior work from the information processing perspective also suggests that task-related dimension of diversity (including different knowledge backgrounds) should increase the task-related information and perspectives available to the group and hence innovative performance (Hulsheger et al., 2009; Stewart, 2006; Van Knippenberg et al., 2004; Williams and O'Reilly, 1998). Thus, knowledge transfer among different knowledge sources generates new combination of knowledge through integration of disparate knowledge elements broadly drawn from different organizations (Lee and Walsh, 2011; Miller et al., 2007).

Given the importance of broad information access, we expect that, due to bounded rationality, projects that draw from a broader team of researchers (representing different fields, institutions and sectors) are likely to produce more technologically significant inventions (Page, 2007; Taylor and Greve, 2006; Van Knippenberg et al., 2004; Williams and O'Reilly, 1998). Hong and Page (2004) use the concept of functional diversity of the problem solving team, which includes both diversity in perspectives and diversity in heuristics. They show (through simulation and mathematical proof) that even a randomly selected set of agents can outperform a set of high ability agents, because the random sample is likely to have higher functional diversity. They argue that the value of an additional agent may depend more on the functional distinctiveness of the additional agent than on the ability of that agent (Hong and Page, 2004). In the case of industrial projects for invention, this suggests that projects that span organizations, and especially types of organizations (heterogeneous projects), are likely to produce higher quality inventions, and that this effect is due to greater breadth of information access (Nooteboom, 2008; Taylor and Greve, 2006). Therefore, more heterogeneous collaboration (i.e., higher diversity in the types of collaborators) will generate more technically novel or significant inventions.

Hypothesis 1. Higher heterogeneity of knowledge sources (at the idea generation stage) will increase invention quality.

This relationship should hold even net of the number of inventors (Hong and Page, 2004).

2.2. Collaboration partners and invention quality

We can think of heterogeneity not only in terms of the number of types of organizations (suppliers, customers, rivals, universities, government labs, etc.), but also in terms of whether it involves cross-sector (university-industry collaboration) or vertical linkages (collaboration with suppliers and customers), which are related to different kinds of knowledge.

To generate invention, firms need to attract those who can provide cutting-edge scientific knowledge (Gittelman and Kogut, 2003). Since universities are particularly broad repositories of