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Two faces of scientific knowledge in the external technology search process

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ABSTRACT

Scientific knowledge enhances the process of external technology search, which is key to generating technological innovations. We propose the interaction effects of scientific knowledge with two technology search dimensions: external technology search intensity (scale) and external technology search scope. We examine these interaction effects in the generation of technological outcomes by comparing between sectors with creative accumulation (hydrogen energy) and creative destruction (nanotech). Data on the U.S. patents and their citations were collected to measure external technology search activities and degree of scientific knowledge in generating technological outcomes. We find that scientific knowledge and high external technology search intensity jointly increase technological outcomes in the sector with creative accumulation and scientific knowledge and broad external technology search scope jointly increase technological outcomes in the sector with creative destruction.

1. Introduction

Technological innovations are a result of a complex process in which a vast diversity of technological components is searched and combined systematically. The technological innovation process consists of prior knowledge search and combining the search results (Carnabuci and Operti, 2013; Fleming, 2001; Henderson and Clark, 1990; Nelson and Winter, 1982; Schulz, 2001). It requires organizations to absorb and identify appropriate knowledge components from intra- and inter-organizations (Paruchuri and Awate, 2017).

Scientific knowledge is an important component for the external technology search process. Prior studies showed that scientific knowledge does not influence technological innovations directly because it does not aim at solving specific commercial problems (Gittelman and Kogut, 2003; Nightingale, 1998; Rosenberg, 1990; Tijssen, 2001). Instead, it could help organizations understand how the whole systems linked to their products work and how to identify appropriate external knowledge efficiently. However, a relationship between scientific knowledge and external technology search activities and its impact on technological outcomes still remain a black box.

There are two distinctive dimensions of the external technology search process: external technology search intensity (scale) and external technology search scope (Alcácer & Zhao, 2012; (Dyer and Singh, 1998; Hall et al., 2001; Laursen and Salter, 2014; Walker et al., 1997)). On the one hand, external technology search intensity indicates how much organizations depend on external technology (Alcacer & Zhao, 2012; (Hall et al., 2001; Schulz, 2001)). Organizations combine in-house technologies with external ones for technological innovations. Utilizing more external technology allows them to make frequent interactions and access abundant technology sets from external actors from a scale view. On the other hand, external technology search scope describes which technology organizations acquire for new knowledge. Boundary-spanning search activities enable a focal organization to seek distant and non-redundant technology beyond a peer group. The marginal effect of integrating non-redundant and broad technological domains is greater than the technology integration effect produced through neighboring domains (Burt, 1992; Rosenkopf and Nerkar, 2001).

These two technology search processes have shown mixed results. Prior studies reported two opposite benefits regarding external technology search intensity and scope (Park and Lee, 2006; Perry-Smith and Mannucci, 2017). For example, the effects of broad external technology search on firm performance can be either positive or negative depending on the business environment (Choi and Park, 2017). In this situation, the sectoral environments have been found to be an important contingent factor in external technology search processes (Malerba and Vonortas, 2009).

Drawing on the organizational learning and network theory, we test two hypotheses. First, scientific knowledge and high external technology search intensity jointly increase technological outcomes.

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Intensive external technology search provides massive information flow, and scientific knowledge can enhance the understanding of this massive external information (Makri et al., 2010) by generalizing the patterns found in external information (Nightingale, 1998). It could be helpful in a sectoral environment with creative accumulation led by large firms with scale-intensive resources for handling complex and systemic features (Malerba and Orsenigo, 1997) such as the hydrogen energy sector because actors in this sector need to acquire substantial external information associated with large technological systems consisting of numerous sub-systems and components.

Second, scientific knowledge improves the effectiveness of an organization's broad external technology search scope. Scientific knowledge can predict valuable technologies for organizations when they explore unfamiliar technological domains (Arora and Gambardella, 1994; Fleming and Sorenson, 2004). This effect becomes critical in a sectoral environment with creative destruction led by small firms offering new business opportunities by integrating separate and distant technological domains (Malerba and Orsenigo, 1997) such as the nanotech sector.

We collected US patent citation data covering 2001 to 2008 using the hydrogen energy and nanotech cases and established networks with which to measure the technology search activities of a focal organization and the degree of scientific knowledge used by patenting organizations in generating technological outcomes. Zero-inflated binomial regression models were adopted to evaluate the interaction effects of scientific knowledge and technology search processes on patent outcomes. This study contributes to the literature on organizational learning with a focus on the use of scientific knowledge and external search processes. First, it reveals the role of scientific knowledge in generating technological innovations. As prior studies noted, scientific knowledge can be an indirect input for technological outcomes (Nightingale, 1998; Rosenberg, 1990; Tijssen, 2001). However, its indirect role in generating technological outcomes has not received systemic investigation, yet (Fleming and Sorenson, 2004). We examine its interaction effects with organizations' external technology search activities as an indirect role in technological innovations (Tortoriello, 2015). Second, we show that the sectoral environment is an important contingent factor associated with the interaction effects between scientific knowledge and external technology search activities by examining conventional sector classification. Doing so enables us to reveal the dual roles that scientific knowledge plays in coupling with external technology search processes.

2. Theory and hypotheses

The organizational learning theory presents that organizations offer the space for knowledge generation (Grant, 1996; Kogut and Zander, 1992). However, technological innovation does not emerge from a vacuum. It is the process of identifying and then combining valuable prior knowledge (Carnabuci and Operti, 2013; Fleming, 2001; Henderson and Clark, 1990; Nelson and Winter, 1982). Knowledge includes both scientific and technological knowledge. It is dispersed across organizations and industrial sectors. An organization searches for new knowledge ahead of merging acquired knowledge components to produce breakthrough innovations (Jung and Lee, 2016).

2.1. The use of scientific knowledge in generating technological innovations

Scientific knowledge is key to advancing technological knowledge. Scientific and technological knowledge are interconnected (Rip, 1992), but science and technology development occur through different motivations and logics (Gittelman and Kogut, 2003). Though organizations gain significant benefits from utilizing scientific knowledge, they tend to underestimate its importance, for two reasons. First, specific business conditions are required in order to reap the benefits of scientific knowledge. According to Henard and McFadyen (Henard and McFadyen, 2005), using scientific knowledge produces superior performance in high-tech sectors, while organizations with low technology obtain no significant gain from scientific knowledge usage. This implies that the effects of scientific knowledge depend on sectoral environments. Second, converting scientific knowledge into technological knowledge requires extra efforts (Gittelman and Kogut, 2003)—for example, in the task of choosing an appropriate technological components.

Science refers to basic and fundament knowledge that provides a core design concept for answering universal scientific questions. It does not focus on specific technological questions. Scientific knowledge begins with known starting conditions and seeks unknown end results, while technological knowledge starts with explicit end results. Thus, many scholars claimed that scientific knowledge cannot be a direct input for producing technology, but have an indirect role in technological outcomes (Gittelman and Kogut, 2003; Nightingale, 1998; Rosenberg, 1990; Tijssen, 2001).

2.2. External technology search process: search intensity and search scope

How can organizations search for useful existing technology? This is an important issue when examining the indirect role of scientific knowledge in generating technological innovations. Pioneers have compared between the effects of local and distant searches. Local searches are organizational activities that pursue solutions based on an organization's position. By contrast, a distant search starts from an organization's distinct areas (Stuart and Podolny, 1996). A distant search occurs beyond the organizational boundary (Gallego et al., 2013; Rosenkopf and Nerkar, 2001). Organizations explore external areas to avoid suboptimal solutions caused by a lock-in conditioned by their own technological domains.

We can consider two different dimensions of external technology search: external technology search intensity (scale) and external technology search scope. External technology search intensity represents the extent to which organizations rely on external technologies in a search process from a scale view, while external technology search scope describes how broadly organizations search for new technology outside (Dyer and Singh, 1998; Hall et al., 2001; Laursen and Salter, 2014; Walker et al., 1997). These two dimensions correspond to actual organizational decisions. When generating technological outcomes, organizations need to choose the appropriate technology search process in their business contexts. First, they choose whether to seek existing technology from an internal technology set or an external technology set and how much they depend on external knowledge. This is related to the external technology search intensity (scale). Second, they choose where to seek technology. It is related to the external technology search scope. Organizations can acquire prior knowledge either from closure networks or from unconnected groups (Rosenkopf and Nerkar, 2001).

We can find two opposite views regarding these two external search dimensions in the literature. In the case of external technology search intensity, prior studies have highlighted the importance of the intensity of external search. They have argued that external search efforts could increase the volume of the interactions and knowledge-sharing with partners (Dyer and Singh, 1998). By contrast, other prior studies have emphasized the internal search process in which organizations can utilize knowledge assets within organizations, resulting in a stable flow of knowledge (Malerba and Orsenigo, 1997; Park and Lee, 2006) and the protection of valuable internal knowledge from external partners (Laursen and Salter, 2014).

Two opposite views have also been discussed concerning external technology search scope. On the one hand, scholars have paid attention to exploration activities moving across peer groups. They have argued that a broad scope of external search plays a key role by spanning distant and unconnected organizations, thereby helping the organizations consider alternative approaches (Ahuja, 2000; Burt, 1992). In this case, organizations focus on inter-peer group activities to obtain the