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Learning and innovation: Exploitation and exploration trade-offs☆

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ABSTRACT

This paper examines the relationship between learning and innovation outcomes, focusing on the trade-off between exploitation and exploration in learning and innovation. The study identifies two types of learning and two outcomes of innovation. Exploitation and exploration in learning are inversely associated with innovation rates and impact. While exploitative, localized learning is positively associated with innovation rates, but negatively associated with impact, exploratory learning-by-experimentation shows the opposite relationship. The study examines panel data of 103 companies in the global pharmaceutical industry over a 7-year period in an empirical test of our hypotheses. Results support the existence of the exploitation and exploration trade-off.

Innovation is one of the most important organizational processes and outcomes for value creation (Deeds, DeCarolis, & Coombs, 2000). Innovation is a central mechanism for strategic change and growth whereby organizations exploit, explore, and reposition themselves in changing internal and external conditions (Dittrich & Duysters, 2007). Both exploitative and exploratory learning govern innovation (March, 1991). Exploitation increases the efficiency of existing technologies, while exploration is required to produce new technologies of high quality and impact (Henderson, 1993). Thus, there is an inherent tension between exploitation and exploration in organizational learning in terms of outcomes of innovative activities (Sorensen & Stuart, 2000).

A few empirical studies differentiate impact from innovation rates as innovation outcomes (see Gittelman & Kogut, 2003; Rosenkopf & Nerkar, 2001; Sorensen & Stuart, 2000). Key to a firm's technology strategy is to strike the right balance between the two major types of learning—exploitative vs. exploratory—depending on what innovation outcomes—rates vs. impact of innovation—the firm is targeting.

The study here asks: How do types of organizational learning shape innovation outcomes? Existing literature suggests that exploitative "localized learning" improves immediate innovation rates, but it often simultaneously reduces incentives for and competence with high-impact innovation (Ahuja & Lampert, 2001). Thus, firms must combine exploitative "localized learning" with exploratory "learning-by-experimentation" if they also want to enhance the impact of innovation.

Although exploitation and exploration and their effects on innovation have been intensively examined (such as in Ahuja & Lampert, 2001), few empirical studies investigate the actual trade-offs between the two. Exceptions include Atuahene-Gima (2005) and Auh and Menguc (2005) in marketing literature. Unlike those studies, which used questionnaire methods, however, this paper employs longitudinal patent data to test empirically the trade-off between exploitation and exploration. Moreover, joint consideration of innovation rates and impact in this study with the inverse relationship between exploitation and exploration enables us to examine the discriminating effects of exploitation and exploration on outcomes of innovation that have not been tested before.

A cursory look at our database in the global pharmaceutical industry shows an interesting pattern: science-intensive firms such as Genentech and Immunex, which focus on exploratory learning, appear to outperform others in terms of innovation impact (refer to Table 2). On the other hand, the most prolific firms in terms of the number of patents, such as Bayer and E. I. DuPont, are among the few that focus on exploitative learning based on strong technological competence. This interesting pattern is consistent with the inherent trade-offs between exploitation and exploration in organizational learning and innovation outcomes that we address in this paper. To provide more rigorous empirical findings, we constructed panel data of 103 companies in the global pharmaceutical industry over a 7-year period and then tested our hypotheses on relationships between types of learning and innovation outcomes. Results support the existence of the exploitation and exploration trade-off.

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1. Model and hypotheses

1.1. Theoretical model: Learning and innovation

The literature on organizational learning (Cohen & Levinthal, 1990; Levitt & March, 1988; March, 1991) and evolutionary economics (Nelson & Winter, 1982; Stuart & Podolny, 1996) distinguishes exploitation from exploration. Both exploitative "localized learning" and exploratory "learning-by-experimentation" shape innovation.

Innovation occurs in the context of a community, one that is evolving as a whole (Gittelman & Kogut, 2003). Hence, firm-level technological trajectories influence, and are influenced by, trajectories of other firms and the evolution of an industry as a whole. At a technology community level, innovations that serve as sources of many subsequent innovations by other firms can be regarded as high-impact (Rosenkopf & Nerkar, 2001). Exploitative "localized learning" helps a firm to produce more innovations, but hinders high-impact innovation. On the other hand, exploratory "learning-by-experimentation" enables a firm to develop high-impact innovations, but impedes innovation productivity. The trade-off is inevitable because the two types of learning require substantially different orientations, strategies, capabilities, and structures (Argyres, 1996; Auh & Menguc, 2005).

Fig. 1 summarizes the theoretical model in this study, which examines the effect of exploitation and exploration on innovation rates and impact. The term "impact" denotes that a technology has been retained and built upon by other members of the technological community. In comparison, the term "innovation rates" refers to the frequency or quantity of new technologies produced.

1.2. Technological competence and innovation

The skills and expertise required for the generation and application of technology become embodied in a set of routines within a firm (Nelson & Winter, 1982). Experience with a given set of routines enhances organizational competence, in part by improving the reliability of the routines (March, 1991). Organizational routines and competencies are often configured around a firm's core technology (Leonard-Barton, 1992). Firm-level variation in competence is a result of the tacit nature and path-dependent development of technology (Helfat, 1994). A firm's core competence is formed by such path-dependent exploitation of technological knowledge (Prahalad & Hamel, 1990). Technological (core) competence refers to the level of efficiency to which a firm carries out its technological routines internally.

The path-dependent accumulation of new knowledge leading to technological development reflects the areas of a firm's core competence (Leonard-Barton, 1992), in which it has conducted a substantial amount of in-house R&D. To some extent, each firm is influenced by the trajectory of its technological development in the past, in that the development of new technology requires the internally accumulated technology for firm to have an absorptive capacity (Cohen & Levinthal, 1990). As such, internally accumulated technological routines and competencies are positively related to a firm's ability to generate new technology along existing technological trajectories (Ritter & Gemünden, 2004).

However, because the behavior is routine-based, technological competence is prone to inertial pressures (Nelson & Winter, 1982). As organizations experience success, their routines and competencies become more standardized and specialized, and integrating superior technologies and practices developed elsewhere may become more difficult and costly for them (Christensen, 1997). Because of the uncertainty that occurs in innovation efforts, the results of past searches become the natural starting points for new searches, and firms thus continue to build on their own established knowledge (Dosi, 1982). Such inertia is especially problematic in fast-changing environments where core capabilities often become core rigidities (Leonard-Barton, 1992).

With respect to innovation, technological competence is always both enabling and constraining (Song et al., 2003). Technological competencies enable firms to exploit innovations more efficiently, but this can substantially constrain the effectiveness of more exploratory innovation (Ahuja & Lampert, 2001). In other words, firms with competence in a particular technology area tend to highly value knowledge that is close to existing successful technological areas, and devalue more distant knowledge that is available outside of the firm. Levitt and March (1988) describe such a situation as a "competency trap."

In their study of the relationship between firm aging and innovation, Sorensen and Stuart (2000) indicate that greater levels of reliance on the firm's own prior developments leads to more innovation, but that this innovation is less relevant, and is therefore a hallmark of obsolescence. In the optical disk industry, Rosenkopf and Nerkar (2001) examine technological impact and find that technology searching within firm boundaries has a negative effect on technological impact. Therefore, we can hypothesize that exploitation of core competence will have a positive effect on innovation rates, but a negative effect on innovation impact due to competency traps.

H1. The technological competence of a firm associates positively with its innovation rates but relates negatively with its innovation impact.

1.3. Science intensity and innovation

Innovation builds on knowledge gleaned from scientific studies (Gittelman & Kogut, 2003). In particular, the pharmaceutical industry, which is our research setting, is dependent on a complex and always-evolving scientific research base, largely because of an increasing reliance on biotechnology for its R&D activities (Henderson & Cockburn, 1994). As a result, the pharmaceutical industry has become one of the most science-intensive sectors in the economy (Pisano, 2006). The ability to take advantage of scientific advances developed elsewhere has become increasingly important to R&D in pharmaceutical firms, and is a major source of competitive advantage (Gambardella, 1992). Although the pharmaceutical industry as a whole is science driven, we still expect to find firm-level variations in terms of science intensity, and for some firms in the industry to conduct more science-driven R&D than others (Cockburn, Henderson, & Stern, 2000).

The term "science intensity" refers to the degree to which a firm builds upon or relies on scientific knowledge for its technology development. Science intensity reflects the tendency for firms to engage in exploratory research (Kim & Park, 2010). Science-based R&D is uncertain and costly, but the payoffs can be high when it is successful, which is a typical pattern for exploratory search (Atuahene-Gima, 2005). When a firm is more science driven in its R&D, it is more likely to appreciate the value of exploration and, consequently, be more willing to engage in exploration in R&D.

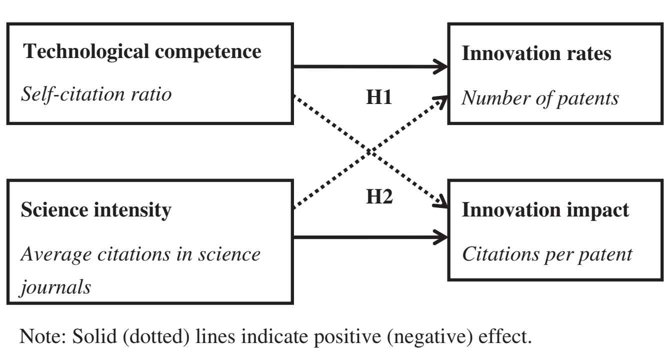

Fig. 1. Theoretical model. Note: solid (dotted) lines indicate positive (negative) effect.