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Knowledge stock, exploration, and innovation: Research on the United States electromedical device industry ☆

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Abstract

This study applies the knowledge-based view of the firm to examine the relationships between exploration, characteristics of knowledge stock, and innovative performance. The article argues that the effectiveness of exploration on innovation is contingent upon two dimensions of knowledge stock: knowledge depth and knowledge breadth. Empirical findings from the US electromedical device industry between 1990 and 2000 provide support for this contingency argument.

Keywords: Exploration; Knowledge stock; Technological innovation

1. Introduction

The competence–rigidity paradox is an interesting topic in strategic management research (Leonard-Barton, 1992; Levinthal and March, 1993; March, 1991). While both exploration and exploitation are essential for firm success and are dependent on each other, how to effectively balance and manage these two processes remains unclear in the literature (Atuahene-Gima, 2005). Some researchers claim that solving this paradox is one of the toughest managerial challenges in creating and sustaining competitive advantage in dynamic environments (e.g., Abell, 1999; Williamson, 1999).

Previous studies attempt to resolve this paradox by examining how exploration and exploitation influence firm performance in various settings (e.g., Atuahene-Gima, 2005; Katila and Ahuja, 2002; Rosenkopf and Nerkar, 2001). For instance, Rosenkopf and Nerkar (2001) examine the effects of search behaviors in the optical disk industry and find that the impact of technological innovations depends on the degree of boundary-spanning exploration activities. Considering exploration and exploitation as two distinct processes rather than as a continuum, Katila and Ahuja (2002) find, in the robotics industry, that exploration and exploitation are complementary when new products are introduced. However, while these empirical studies are illuminating, few studies have taken into consideration other contingency factors that influence the linkage between exploration–exploitation and innovative performance, such as the firm's existing knowledge stock. As Nelson and Winter (1982: 172) point out: "Real search processes take place in specific historical contexts, and their outcomes clearly depend in part on what those contexts contain in the way of problem solutions that are available to be 'found'."

This study fills in this research gap by applying the knowledge-based view to investigate how exploration and knowledge stock interact with each other and influence firm performance. In particular, this study addresses the above question in the setting of technological innovation, and focuses on the moderating role of current knowledge stock on the effect of exploration. The recent knowledge literature suggests that the growth of firm knowledge is a function of knowledge stock as well as continuous search for new knowledge elements and potential integration opportunities (e.g., Kogut and Zander, 1992). Knowledge stock reflects the amount of knowledge elements that a firm has accumulated over

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time (Dierickx and Cool, 1989) and is embedded in organizational routines, technologies, employees, and other types of resources (Grant, 1996). Exploration captures the extent to which new knowledge is acquired (Katila and Ahuja, 2002). More specifically, exploration in this study refers to the integration of new knowledge elements that locate outside a focal firm. For instance, Firm A may cite a patent that has never been cited by itself before. Then this patent becomes a new knowledge element to Firm A, and Firm A is exploring something new from the outside world.

Existing theories suggest that knowledge stock and exploring new knowledge are inter-dependent in that existing knowledge stock not only provides incentives to acquire new knowledge, but also shapes the scope and direction of future exploration (Katila and Ahuja, 2002; Penrose, 1959). On the other hand, newly generated knowledge is converted to knowledge stock and thus facilitates the growth of knowledge stock (Smith et al., 2005). The present study examines the joint effects of knowledge stock and exploration on innovative performance and pursues two research questions. First, how does a firm's exploration influence its innovative performance? Second, how does a firm's existing knowledge influence the relationship between exploration and the firm's innovative performance?

2. Theoretical development and hypotheses

2.1. Exploration and innovative performance

Technological search processes aim at creating new knowledge (Cohen and Levinthal, 1990). Previous studies show that firms differ in their search behaviors and capabilities. Due to the constraints of time, budget, and technologies, most firms tend toward local search (March, 1991; Stuart and Podolny, 1996), making use of their current areas of expertise. This exploitation focuses on "the refinement and extension of existing competences, technologies, and paradigms" (March, 1991: 85). The alternative, exploration, is "experimentation with new alternatives" (March, 1991: 85). Compared to exploitation, exploration is more likely to be associated with risk-taking, uncertainty, and long-term orientation.

Exploitation has a number of advantages, such as familiarity with knowledge elements, reduction of learning time and costs, and avoidance of potential experimentation mistakes (Fleming, 2001; March, 1991). However, these benefits of exploitation do not last forever. From a technological point of view, returns to exploitation decrease over time (Sahal, 1985). Given a set of knowledge components, the number of possible recombinations is limited. Kim and Kogut (1996) and Fleming (2001) suggest that when a group of technologies are repeatedly applied, the potential for future combinations among these technologies become exhausted. Part of this effect comes from the diminished ability of developers to conceive of new applications. The "imaginary life cycles" (Henderson, 1995) of new product developers tend to petrify, making them less likely to incorporate new components into their products. Also, too much reliance on exploitation forms competency traps and leads to core rigidity (Leonard-Barton, 1992). Thus, a balance between exploitation and exploration is important.

Exploration plays an important role in technological innovations (Ahuja and Lampert, 2001; Katila and Ahuja, 2002; Rosenkopf and Nerkar, 2001). First, exploration enlarges a firm's search scope and brings more new knowledge elements into the firm. As the number of knowledge elements increases, the potential number of architectural innovations also increases (Henderson and Clark, 1990). Second, when a firm explores new knowledge elements, it gets access to different technological areas, thus adding heterogeneity to a firm's existing knowledge. The newly explored elements may differ from the existing ones in terms of problem identification, formulation, and solution. As the knowledge literature suggests, diversity and heterogeneity help in new knowledge creation. Actually, more influential innovations become possible when a firm experiments with new knowledge from distant technological areas (Rosenkopf and Nerkar, 2001). Third, experimenting with new knowledge also helps firms avoid core rigidity. Core rigidity originates from the local search along a firm's existing technological trajectory and from ignorance of external technological dynamics (Leonard-Barton, 1992). By searching widely in distant technological domains, the firm can keep itself updated with the latest developments in a domain. By itself, this alertness to the external environment helps a firm avoid the competency trap so that the firm can pursue more consistent innovation activities.

However, exploration does not always benefit innovation. Several researchers point out that over-exploration actually constrains innovative performance. For instance, Ahuja and Katila (2001) argue that when a firm suddenly acquires a large technological base, the innovation process is hindered for two reasons. First, search and integration require resources, time, and relevant supporting mechanisms. In fact, given a large set of new knowledge elements, choosing areas for trials becomes more costly and fewer data are available to support decision making. The costs of integrating search results also increase, especially when the distance between a firm's current knowledge base and its new knowledge increases (Penrose, 1959). Subsequently, over-exploration leaves fewer resources for actual innovation activities. Second, wide search and the new knowledge that the search introduces into a firm may disrupt organizational routines and even spark conflicts among current members (Iansiti, 1997). Furthermore, experimentation that is too wide may reduce overall productivity due to its decreasing reliability (Martin and Mitchell, 1998). By integrating the above arguments, this study comes to the following hypothesis.

H1. Exploration has an inverted-U shaped relationship with innovative performance when all else is equal.

2.2. Moderating effects of knowledge stock

Innovation scholars commend exploring new ideas and developing new knowledge, especially in dynamic environments where new technologies are booming, old technologies become obsolete quickly, and products have short life cycles. In such environments, firms need to maintain the momentum for exploration in order to keep up with new technological developments.

However, technological search is path-dependent in that existing knowledge stock serves as the starting point and