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Balancing exploration and exploitation in inventions: Quality of inventions and team composition

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ABSTRACT

Building upon the exploration and exploitation framework, this study investigates the antecedents and consequences of inventions that balance new and existing knowledge. Using patent data from the semiconductor industry, this paper evaluates the quality of inventions that involve different levels of exploration. It finds that balanced inventions that combine a firm's existing knowledge with new knowledge are of higher quality than inventions that are either over-exploratory or over-exploitative. Furthermore, this study investigates how teams can be composed to create balanced inventions. Results show that teams of a moderate size and with a moderate level of invention experience (both general and specific) are more likely to create inventions that balance exploration and exploitation.

1. Introduction

Management and innovation scholars have widely argued that the ability of firms to balance exploration and exploitation – referred to as organizational ambidexterity – is critical for sustained performance over time (Cao et al., 2009; He and Wong, 2004; Tushman and O'Reilly, 1996). Realizing ambidexterity, however, entails the coexistence of opposing structures and processes that create paradoxical challenges (Smith and Tushman, 2005). In order to deal with these challenges, studies have primarily provided a firm-level perspective, and have advocated the use of differentiated units for exploration and exploitation where there is targeted integration between the units or their activities (Jansen et al., 2009; Raisch and Birkinshaw, 2008). However, current perspectives on organizational ambidexterity suggest that the achievement of ambidexterity has also become more and more prevalent at lower hierarchical levels (Gibson and Birkinshaw, 2004; Haas, 2010) as a means of responding adequately to emerging technologies. Indeed, scholars have suggested that high-tech firms rely more heavily on teams to balance exploration and exploitation within inventions, and to enact new and existing knowledge when developing novel technologies (Tushman et al., 2010; Jansen et al., 2016). Although it is plausible, indeed even intuitive, that a firm's inventions may act as valuable and effective platforms for technological advancement (Singh and Fleming, 2010), we still lack an in-depth understanding of the

factors that enable firms to balance exploration and exploitation when developing inventions, and what effects such balance may have. These insights are crucial, though, because of the importance for high-tech firms to create high-quality inventions that may lay the foundation for future technological developments (Podolny and Stuart, 1995; Singh, 2008).

In this paper, we address this gap by investigating the antecedents and consequences of balanced inventions. First, we examine the relationship between the degree of exploration involved in an invention and the quality of that invention, defined as the extent to which the invention makes significant scientific and technological progress and directs future development (Singh, 2008). Earlier studies have addressed some antecedents of invention quality such as collaboration networks (Singh, 2008), technological complexity (Sorenson et al., 2006), backward science (Sorenson and Fleming, 2004), and firm status (Podolny and Stuart, 1995). Nevertheless, some fundamental aspects into the exploratory nature of inventions have been overlooked (Nerkar, 2003; Benner and Tushman, 2002). An invention's exploration refers to the extent to which the invention goes beyond a firm's existing knowledge and includes new knowledge (Benner and Tushman, 2002). In other words, exploration is used here to denote the amount of new knowledge underpinning an invention, whereas exploitation represents the amount of existing knowledge.¹ Following earlier studies, we consider exploration and exploitation within inventions as two ends on a

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¹ Exploration is different from newness/innovativeness. Exploration refers to the extent to which new knowledge is included in a firm's inventing process, while newness relates to the outcomes of inventions or the extent to which they turn out to be novel. Newness/innovativeness thus focuses more on innovations of products, rather than inventions (Schultz et al., 2013).

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continuum (March, 1991; Lavie and Rosenkopf, 2006; Uotila et al., 2009). Although scholars have suggested that exploration may contribute to invention quality because of the inclusion of new knowledge components (Wang et al., 2014), we argue that whenever firms enter new domains in which they have less credibility and legitimacy (Zuckerman, 1999) – as they do when they engage in too much exploration—greater uncertainty and complexity is introduced. Given these potential downsides, we argue that higher quality is likely to be derived from a moderate degree of exploration – i.e., inventions with a balance between exploration and exploitation.

Second, although inventions are often developed by a team of inventors (Wuchty et al., 2007), we have a limited understanding of how the composition of such a team may affect its propensity to balance exploration and exploitation within inventions. Importantly, scholars have argued that the composition of invention teams may significantly affect the outcomes they achieve (Singh, 2008; Gruber et al., 2013). For instance, it has been shown that teams with more diverse knowledge may experience fewer failures (Singh and Fleming, 2010), and teams with more generalists may enhance the economic relevance of inventions (Melero and Palomeras, 2015). However, these insights do not explain how team composition may determine the extent to which teams balance exploration and exploitation in their inventions. Due to learning myopia (Levinthal and March, 1993) and experience inertia (Liao et al., 2008), teams usually tend to exploit their current knowledge stock, but lack the motivation to search for new knowledge (Sørensen and Stuart, 2000; Ahmadi et al., 2017). At the same time, tensions between exploration and exploitation (Lavie et al., 2011) make it more difficult for them to balance new and existing knowledge in an appropriate way. In order to move research forward, our study discusses what effects the size of a team and the team's invention experience (both general and specific) have on the team's propensity to balance exploration and exploitation within inventions.

We tested our hypotheses using a sample of patents applied for by semiconductor firms between 1991 and 2001. In an analysis of more than 36,000 patents, we find that balanced inventions are around 4.7% higher in quality than inventions that are either over-exploratory or over-exploitative. We also find that teams of a moderate size (i.e., with about four team members) and teams with a moderate level of invention experience (both general and specific) are more likely to balance exploration and exploitation in their inventions. In other words, although larger teams with more invention experience are less prone to over-exploration, they are also more likely to come up with inventions that are over-exploitative.²

2. Literature review and hypotheses

2.1. Balancing exploration and exploitation

Originating from organizational learning, the concepts of exploration and exploitation (March, 1991) have been examined at multiple levels of analysis (Raisch and Birkinshaw, 2008), including the firm- (Uotila et al., 2009; Phelps, 2010), subunit- (Jansen et al., 2012), team- (Beckman, 2006), individual- (Lee and Meyer-Doyle, 2017), and invention-level (Nerkar, 2003). Moreover, research on the nature of exploration and exploitation has examined this topic from various angles, ranging from how new knowledge is introduced to how firms extend their geographical scope or how they look for new partnerships (Lavie and Rosenkopf, 2006). When focusing on exploration and exploitation within high-tech industries, scholars have particularly stressed the idea that it is important for firms to combine new and existing knowledge in their innovation portfolios (Wang and Li, 2008).

Exploration involves the search for new knowledge that firms can use

to find appropriate solutions to technological problems. However, an overemphasis on exploration may be dysfunctional and harmful for leveraging opportunities and generating technologies (Katila and Ahuja, 2002; Wang and Li, 2008). On the other hand, if firms focus solely on exploitation, they may succumb to inertia and become somewhat myopic, thereby failing to spot new opportunities or to respond to emerging technologies. Scholars have therefore argued that firms need to become ambidextrous by balancing exploration and exploitation when building their innovation portfolios (Raisch and Birkinshaw, 2008).

2.2. Balancing exploration and exploitation within inventions

Inventing is the process of recombining knowledge in order to find solutions to technological problems (Nelson and Winter, 1982; Fleming, 2001). Firms and people often tend to confine their search for knowledge to technological domains with which they are already familiar, and invent by recombining existing knowledge (Sørensen and Stuart, 2000). However, even though inventors may continue to exploit a firm's existing knowledge in depth (Katila and Ahuja, 2002), the added value that existing knowledge can bring to the market gradually becomes exhausted, because there is a limit to the number of ways in which existing knowledge can be usefully combined (Fleming, 2001). A change in the competitive environment or a shift in technology trajectory may also mean that a firm's existing knowledge becomes outdated (Jansen et al., 2006; Wu et al., 2014). Inventions that do not match current market needs will be given a rough ride (Sørensen and Stuart, 2000). As such, inventions that employ only existing knowledge have their limitations, and for an invention to be of high quality, it will almost certainly need to incorporate new knowledge.

By introducing new knowledge into an invention, firms can overcome the problem of local search (Wang et al., 2014). Inventions that combine new knowledge with existing knowledge are more likely to offer the market something new and distinctive. Knowledge that is new to a firm increases technological variation (Baum and Singh, 1994), which is valuable for finding better solutions to technological problems (Katila and Ahuja, 2002). In addition, incorporating new knowledge into an invention is likely to open up previously undiscovered technological opportunities and potential (Fleming et al., 2007), which may attract more firms or inventors to follow. Thus, inventions that draw on some new knowledge are likely to be of higher quality than those that only recombine existing knowledge.

However, when the proportion of new knowledge within an invention becomes too high, the added value associated with exploration may be eroded. First, inventions that involve a relatively high degree of exploration do not capitalize on a firm's existing knowledge base. Existing knowledge reflects a firm's current expertise and is a source of its core competence (Grant, 1996). Firms are usually better at employing and transforming the knowledge they already possess into appropriate and competitive market offerings. An invention that involves too much new knowledge does not fully utilize a firm's advantage and core competence, and is thus less likely to be competitive in the market. Second, although new knowledge increases diversity, it also poses challenges (Katila and Ahuja, 2002). In particular, inventing firms will have less understanding of how best to apply the new knowledge, so they will face greater uncertainty when creating inventions that build largely on new knowledge. The inclusion of more new knowledge sources from other firms usually means that a firm is entering an area where the other firms already have a foothold and advantage, thus decreasing the likelihood that the invention will be particularly valuable. Moreover, we contend that the quality of an invention is also socially constructed (Podolny and Stuart, 1995). The impact and quality of an invention is determined not only by the nature of the knowledge involved (Fleming, 2001), but also by the characteristics of the firm that develops it (Podolny and Stuart, 1995). Actors in the market tend to put firms into different categories, based on the firms' main activities (Zuckerman, 1999). They will perceive a firm's inventions as being more credible and legitimate if the inventions are consistent with its established expertise. When a firm invents something in a completely new

² In our theorizing, inventions are categorized into three types: balanced inventions that combine a moderate level of both new and existing knowledge, over-exploratory inventions that include too much new knowledge, and over-exploitative inventions that combine too much existing knowledge.

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