



# Interdependence among productive activities: Implications for exploration and exploitation



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## ABSTRACT

The objective of this study is to explore how the level of interdependence and that of decomposability at the industry level moderate the contribution of exploration and exploitation to firms' long-run financial performance. We employ patent data to measure interdependence and decomposability and computer-assisted content analysis to derive firms' orientations toward exploration and exploitation. We also introduce statistical techniques to control for biases in estimates induced by potential sources of endogeneity. Based on our analysis, in industries that exhibit high levels of interdependence and low levels of decomposability, exploration becomes more necessary to improve firms' long-run financial performance. On the other hand, in industries that exhibit more limited levels of interdependence and high levels of decomposability, exploitation becomes more beneficial to firms' long-run financial performance. We hope our findings will stimulate future research on a number of distinct but related issues, including exploration, exploitation, interdependence, and decomposability, and thus contribute to improve our understanding of organizational success.

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## 1. Introduction

When is it beneficial for firms to invest either in the exploration of new combinations of productive activities or in the exploitation of existing ones in order to achieve greater long-run performance? This question has inspired a wide range of studies in different domains, including organizational learning and strategy (e.g., Levinthal & March, 1993; March, 1991), innovation (e.g., Danneels, 2002), the search for new technologies (e.g., Fleming, 2001), organizational design (e.g., Tushman & O'Reilly, 1996) and entrepreneurship (e.g., Shane & Venkataraman, 2000). Despite such extensive literature, the posed question still raises a dilemma. On the one hand, organizations must invest in exploratory search in order to innovate, while also considering that exploration exposes the firm to greater risks of failure and increases the costs of integrating new processes and products with well-established ones. On the other hand, organizations must invest in exploitation in order to limit search costs, and more easily reap the benefits of already deployed combinations. Yet, an organization that focuses more on exploitation may suffer an expanded risk of obsolescence and declining benefits in the long-run (Levinthal & March, 1993; Levitt & March, 1988). Therefore, how can managers know whether paying more attention toward exploration or exploitation is conducive to higher firms' long-run performance?

An important stream of the extant literature on complex adaptive systems begins to unfold this issue by illustrating how the long-run performance effects of exploration and exploitation are influenced by the interdependencies that characterize the environment in which organizations operate (Lenox, Rockart, & Lewin, 2006, 2007; Levinthal, 1997; Rivkin & Siggelkow, 2007). Interdependencies exist whenever the value of conducting a given productive activity or set of productive activities depends on how an organization conducts other activities (Lenox, Rockart, & Lewin, 2010). Activities that are subject to interdependencies typically include those related to the introduction of new aspects of organizational forms, new features in the manufacturing processes and/or new product characteristics (Lenox et al., 2010: 121).<sup>1</sup>

Using simulation methods, prior theoretical studies have captured interdependencies and show that the higher the level of interdependence, the greater the number of sub-optimal combinations of productive activities that firms may encounter in their search activities, and the greater the risk for firms of being trapped into inferior combinations of productive activities (Levinthal, 1997). If organizations wish to cope effectively with interdependencies, they must broaden their search and focus more on exploration and less on exploitation. In particular, a

<sup>1</sup> The presence of interdependencies among productive activities implies, for example, that, in semiconductor industry, changing the technology for a mask will either improve or worsen the performance of technologies used by the firm to align the mask with the semiconductor. Another example is the introduction of a computer-aided engineering system that may require changes in other activities for the production process to work properly (e.g., the introduction of computer-aided manufacturing workstations and/or flexible manufacturing systems).

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greater focus on exploration allows organizations to extend the number of alternatives and trajectories within their reach, limits the risk of becoming prematurely locked into inferior alternatives, and mitigates the risk that changes in interdependencies will rapidly render currently deployed combinations obsolete (Levinthal, 1997; Rivkin & Siggelkow, 2006). Although both exploration and exploitation are needed to improve long-run performance, high levels of interdependence may thus render exploration more beneficial than exploitation to improve long-run financial performance.

Extant theoretical studies have then illustrated how not only the level of interdependence but also the structure of such interdependencies (i.e. the underlying pattern of interactions among productive activities at the industry level) may influence the long-term benefits of an organization's exploratory and exploitative efforts. In particular, we refer to decomposability as the distribution pattern of interdependencies (Ethiraj, Levinthal, & Roy, 2008; Rivkin & Siggelkow, 2007; Yayavaram & Ahuja, 2008; Zhou, 2013). A set of productive activities is highly decomposable when interdependencies among individual groups of activities are limited in number and weak in intensity as compared to those occurring within each group, which are many in number and strong in intensity (Simon, 1962, 2002). Scholars have emphasized the ambivalent implications of decomposability on the benefits of exploration and exploitation to long-run performance. It has been argued that the tendency of productive activities to be decomposable, on the one hand, renders exploration essential to improve long-run performance because it expands the number of sub-optimal alternatives and therefore the complexity faced by organizations in their adaptive processes (Rivkin & Siggelkow, 2007). On the other hand, the higher the level of decomposability, the easier it is for organizations to observe, understand and even cope with interdependencies among productive activities, thanks to reduced design and cognitive complexity, which makes exploration both less effective than exploitation for firms' long-run performance and more vulnerable to imitation (Ethiraj & Levinthal, 2004; Frenken, Marengo, & Valente, 1999).

Notwithstanding such contributions, extant literature on interdependencies among productive activities remains largely theoretical or still relies on computer simulation. More empirical evidence is therefore required on the moderating effect of interdependencies, and on how it conditions a firm's long-term financial performance. Note that testing the propositions developed within extant theoretical studies represents an important task for empirical research (Davis, Eisenhardt, & Bingham, 2007) and, as observed by Lenox et al. (2007), developing good ways to measure interdependencies is one of its biggest challenges.

In this study, we contribute to the literature by providing a large-scale empirical test of the basic theoretical relationships between exploration, exploitation and long-run performance, controlling for the moderating effect of interdependence. These relationships are analyzed in a longitudinal panel research design that covers the years 1989–2008 for 460 firms included in the 1989 Standard & Poor's 500 (S&P 500) and 400 (S&P 400) indexes. We clarify the moderating role of interdependencies at the industry level, showing whether such interdependence can magnify, attenuate, or even reverse the effects of exploration and exploitation on firms' long-term financial performance. In that, we provide empirical ground to extant theoretical studies that relate interdependencies, exploration, exploitation and firms' long-run performance. In addition, we develop reliable measures of interdependence based on public available data. Furthermore, the proposed measures vary not only across industries but also over time. The availability of time-varying measures of interdependence and decomposability makes it possible to control for the causality relationships among our main independent variables and allows us to use econometrical methods able to control for potential distortions of estimates induced by endogeneity and unobserved heterogeneity (Hamilton & Nickerson, 2003).

Overall, this study provides a fuller understanding of how organizations may successfully respond to multiple environmental conditions

through pursuing exploratory and exploitative search strategies. Interdependence matters, and may lead to diverse performance outcomes for exploration and exploitation activities. Interdependence should thus be placed among the most central concepts in the business field.

## 2. Literature review and hypothesis

As observed by March (1991), the relationship between the exploration of new possibilities and the exploitation of old certainties is crucial to studying firm performance over the long-run. Exploration includes things captured by terms such as “search, variation, risk taking, experimentation, play, flexibility, discovery, innovation.” Exploitation includes such things as “refinement, choice, production, efficiency, selection, implementation, execution” (p. 71).

Interpreted in March's spirit, exploration refers to distant, system-wide search. In such broad terms, exploration is associated with path breaking, improvisation, autonomy and chaos, and emerging markets and technologies (March, 2006). In essence, an organization enacts exploration by broadly spanning numerous and unprecedented combinations of individual activities. Involving a system-wide perspective, a wider time commitment and a broader space horizon (March, 2008), exploration helps fight organizational myopia and competency traps (Levitt & March, 1988) and extends a firm's search beyond the neighborhood of currently known alternatives (Abernathy & Clark, 1985; Fleming, 2001; Rosenkopf & Nerkar, 2001). In addition, exploration stimulates the development of new skills and capabilities, which reduces the risk of becoming obsolete (Leonard-Barton, 1992). It also favors experimentation with expanded sets of opportunities lying beyond local alternatives, which leads to the introduction of new products and production processes, the creation or access to new markets, and the regeneration of consumer value (Fleming & Sorenson, 2001). These outcomes are expected to contribute positively to the organization's long-run financial performance (Lewin, Long, & Caroll, 1999).

Exploitation involves the introduction of new combinations that grow out of the old by continuous adjustments, in small steps, and implies a relatively restricted search for alternatives that complement an existing technology. Exploitation thus allows an organization to reduce the likelihood of errors and false starts, and facilitates the development of routines, making search more reliable (Levinthal & March, 1981). Moreover, it favors the use of accumulated knowledge, which boosts the firm's ability to introduce new products or new productive processes that in many important ways may be not apparent to less experienced organizations (Katila & Ahuja, 2002). By reducing variety, increasing efficiency in current operations, and enhancing adaptation within current markets and with existing customers, exploitation matters for firms' long-run financial performance (Lavie, Stettner, & Tushman, 2010).

### 2.1. The moderating role of interdependence on the long-term financial performance effects of exploration and exploitation

Both exploration and exploitation are necessary for (March, 1991) and influence firms' long-run financial performance (Jansen, Van den Bosch, & Volberda, 2006). However, the net benefits of these search activities depend at least on two different components: search costs and payoffs stemming from such activities (Levinthal & March, 1993; March, 1991). Extant complexity literature has also examined how the presence of interdependence that characterize the environment in which organizations operate influences the net benefits of exploration and exploitation (Ethiraj & Levinthal, 2004; Lenox et al., 2006, 2007; Levinthal, 1997; Rivkin & Siggelkow, 2007). Interdependence manifests itself when the value of a given activity is dependent upon the characteristics of the activity itself as well as upon the characteristics of other productive activities. Interdependence is here conceived to be an industry-level attribute that is faced by all the firms belonging to a given industry rather than chosen by the firm itself. We instead treat

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