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The antecedents and innovation consequences of organizational search: empirical evidence for Spain*

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Abstract

This paper examines the antecedents and innovation consequences of the methods firms adopt in organizing their search strategies. From a theoretical perspective, organizational search is described using a typology that shows how firms implement exploration and exploitation search activities that span their organizational boundaries. This typology includes three models of implementation: ambidextrous, specialized, and diversified implementation. From an empirical perspective, the paper examines the performance consequences when applying these models, and compares their capacity to produce complementarities. Additionally, since firms' choices in matters of organizational search are viewed as endogenous variables, the paper examines the drivers affecting them and identifies the importance of firms' absorptive capacity and diversified technological opportunities in determining these choices. The empirical design of the paper draws on new data for manufacturing firms in Spain, surveyed between 2003 and 2006.

Keywords: exploration-exploitation search, absorptive capacity, technological opportunities, complementarities, firm performance.

JEL Classification: D21; L21; O32

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1. Introduction

Innovation is the process by which firms must properly integrate various search activities to guarantee success in creating knowledge (Kogut and Zander, 1992). However, these activities usually give rise to tensions in their implementation, since they have dissimilar objectives, require alternative organizational capabilities, and can lead to different results. Recent studies in the field of innovation draw on March's (1991) notions of "exploration" and "exploitation" to characterize the pool of search activities encountered in the innovation process, and to examine the tensions emerging from their combined implementation (e.g., He and Wong, 2004; Lavie and Rosenkopf, 2006; Rothaermel and Alexandre, 2008). In these studies, search strategies related to the discovery of new knowledge are aligned with exploration, while those that address the learning of current knowledge are associated with exploitation. Despite differences in their objectives and outcomes, it is widely recognized that both types of strategy are needed in order for firms to enhance their innovation performance (March, 1991; Katila and Ahuja, 2002; Nerkar and Roberts, 2004; Laursen and Salter, 2006).

Given the tensions that can arise from the adoption of conflicting search activities, the ways in which firms choose to implement them is important if we are to understand the firm's strategic choices on different models of organizational search[1]. A review of the literature shows that firms broadly organize exploration and exploitation activities by implementing them in two alternative modes: "simultaneous implementation" and "single implementation" (e.g., Gupta et al., 2006; Chen and Katila, 2008). The former is grounded on the notion of organizational ambidexterity, defined as the ability to execute activities that simultaneously pursue different aims (Tushman and O'Reilly, 1996). By taking this approach, it is argued that the joint adoption of exploration and exploitation search strategies enhances opportunities to combine diverse

[1] See, regarding methods of implementation: Rosenkopf and Nerkar (2001), Katila (2002), Katila and Ahuja (2002), He and Wong (2004), Laursen and Salter (2006), Sidhu et al., (2007) Rothaermel and Alexandre (2008), and Katila and Chen (2008), among others.

sources of knowledge, allowing firms to take advantage of synergies in learning[2]. In terms of their search strategies, Nokia Corporation or GlaxoSmithKline Plc commonly appears in the innovation management literature as examples of ambidextrous organizations (e.g. Birkinshaw and Gibson, 2004). By contrast, the second mode holds that organizational ambidexterity is inefficient, because of the cost involved in combining search strategies that focus on conflicting objectives[3]. Specializing (temporally or permanently) in one or other of the two strategies (i.e., exploration or exploitation) is proposed as a better course of action for mitigating tensions in their implementation. Chen and Katila (2008) document the use of a single implementation (i.e. temporal) in the case of Pixar Animation Studios. By using short-films, Pixar first experiments with new technical features of a movie. After identifying successful ideas with potential applications, the company exploits them by using full-length films.

While previous literature on these modes of implementing exploration and exploitation has advanced our understanding of organizational search, little is known about the performance implications associated with each of these implementation strategies (Rosenkopf and Nerkar, 2001, and Rothaermel and Alexandre, 2008 are notable exceptions). Moreover, while firms span exploration and/or exploitation search across their organizational boundaries, hybrid organizational forms of ambidexterity/specialization are feasible. The performance consequences of these alternative organizational forms for the firm's search activities deserve more attention. Altogether, these issues raise the following questions: (1) How do firms implement different search strategies in organizing exploration and exploitation search across their organizational boundaries? (2) What consequences do the adoption of different models of organizational search have on firms' innovative performance? (3) Which factors can explain the performance heterogeneity derived from particular models of organizational search?

[2] Empirical studies supporting this view include Katila and Ahuja (2002), Katila (2002), Rosenkopf and Nerkar (2001), Nerkar and Roberts (2004), among others.
[3] Empirical studies supporting this view include Rothaermel and Deed (2004), Holmqvist (2004), among others.

In order to address these questions, in this study we first draw on the innovation management literature to build a typology that characterizes alternative models of organizational search. As a second step, we examine the *innovation consequences* derived from particular combinations of search strategies, paying the attention on the production of complementarities that may emerge from each combination. Furthermore, we examine factors that drive the organizational search described by our typology. As discussed below, these factors are viewed here as the *antecedents* to firms' choices regarding their search strategies.

This paper aims to make the following contributions to the literature on innovation management. In terms of firm performance, the current study is the first to compare complementarities associated with alternative combinations of exploration and exploitation search activities, occurring in both intra- and inter-organizational contexts. Although a number of studies have analyzed the link between ambidextrous models of explorative and exploitative search and their impact on performance (e.g., He and Wong, 2004; Rothaermel and Alexandre, 2008), the recognition of alternative models of organizational search and the evaluation of their capacity to produce complementarities remains unaddressed. The assessment of such complementarities deserves more consideration since firms usually seek new knowledge by using a collection of search strategies that are commonly interrelated (Katila and Ahuja, 2002; Nerkar and Roberts, 2004; Lavie, 2007; Williams and Lee, 2009). Hence, the performance evaluation of different models of organizational search should consider potential synergies and trade-offs associated with the implementation of a portfolio of search strategies.

Finally, when examining the link between organizational search and performance, we consider firms' choices regarding models of organizational search to be endogenously determined. Specifically, we examine the role played by a range of factors, including a firm's absorptive capacity (henceforth, ACAP) and its diversity of technological opportunities, in determining its organizational search strategies. By so doing, we seek new evidence for the hypothesis that ACAP contributes to mitigating tensions derived from combining exploration and exploitation search activities across firms' boundaries, as well as evidence to support the premise that environments with diversified technological opportunities induce firms to combine different search strategies to harness external knowledge effectively. Although the moderating role of some of these factors in the relationship between a firm's knowledge search behaviour and performance have been recognized by recent studies (e.g., Jansen et al., 2006; Sidhu et al., 2007; Rothaermel and Alexandre, 2008), our paper seeks to add to this literature by demonstrating that these factors not only affect performance directly, but that they also have an indirect impact by determining firms' choices regarding search strategies.

The rest of this paper is organized as follows. In the next section, we present a theoretical foundation for studying the antecedents and innovation consequences of organizational search. Subsequent sections present our dataset, the estimation methodology, and results. Finally, we provide a discussion and conclusions.

2. Theoretical background

Innovation involves several distinct stages in which firms combine alternative sources of learning. In some of these stages, firms learn from the process of discovering new market and/or service opportunities, while in others firms learn from the process of developing current opportunities. As is suggested by a number of influential studies, these forms of learning are to be found within and/or outside the firms' boundaries[4] (e.g., Powell et al., 1996; George et al., 2001; Rosenkopf and Almeida, 2003; Faems et al., 2005). Thus, in order to organize their search strategies properly, firms must evaluate two sources of tension; one associated with the combined adoption of explorative and exploitative search, and the other related to the integration of internal and external search activities (Katila, 2002; Rothaermel and Alexandre, 2008).

[4] In line with Katila and Ahuja (2002), "search" is understood here as a form of learning in that it allows firms to solve problems and so to innovate.

Here, we focus our attention on internal and external search activities that occur in the context of technological innovation[5]. Internal search involves activities of research (exploration) and development (exploitation). The former refers to the research effort made by firms in seeking out new opportunities that might be exploited, while the latter refers to the research effort dedicated to improving the technologies by which firms can exploit existing opportunities (Danneels, 2002; Nerkar and Roberts, 2004; He and Wong, 2004). Similarly, external search may encompass the forming of alliances centered on activities of exploration and exploitation. The former include those external links in which partners seek novel sources of knowledge in order to create new products or patent new technologies. The latter refer to alliances where partners pool complementary resources that probably neither partner is willing to develop in-house (Koza and Lewin, 1998; Rothaermel and Deeds, 2004; Lavie and Rosenkopf, 2006).

2.1 Models of organizational search

Figure 1 presents a typology identifying alternative models for the undertaking of organizational search. It is derived from the options available to firms regarding how they implement exploration and exploitation search within and outside their organizational boundaries. According to Figure 1, firms face three options when deciding how to put their search strategies into practice: i) "not to implement any strategy", ii) to apply a "single" implementation, or, iii) to opt for the "simultaneous implementation" of both exploration and exploitation search activities. When firms choose to implement overlapping strategies both internally and externally, the typology generates three generic models of organizational search: the "ambidextrous", "specialized," and the "diversified" models. The types of search models depicted in this typology are described in more detail below.

[Insert Figure 1 here]

[5] The exploration-exploitation framework has not only been used to analyze tensions in the innovation process, but also those derived from the adoption of other organizational strategies. These include the duality between flexibility and efficiency (Adler et al., 1999), stability and change (Baden-Fuller and Volberda, 1997), and centralization and decentralization (De Satntis et al., 2002).

Ambidexterity refers to those models of organizational search in which exploration and exploitation are conducted simultaneously. As recognized by several studies (e.g., March, 1991; He and Wong, 2004; Gupta et al., 2006; Rothaermel and Alexandre, 2008), these types of search activities are widely incompatible, since they compete for scarce resources, focus on different goals, and require alternative organizational capabilities. Despite these incompatibilities, ambidexterity can be achieved when knowledge creation is broken down into specialized activities that are carried out by autonomous and highly differentiated units in the innovation process. Finally, it is worth mentioning that, since ambidexterity in searching involves the implementation of exploration, we assume here that ambidextrous models span technological boundaries in that the discovery of new sources of knowledge is also addressed.

In our context, we propose three scenarios in which ambidexterity can arise. First, *internal ambidexterity* can occur at the firm level, so that a number of technological subunits within the firm specialize in exploration while others specialize in exploitation. Despite the presence of important technological opportunities in their environment, some companies keep their major R&D effort in-house (Williams and Lee, 2009). For instance, when innovating before its competitors, a firm has a "first-mover advantage" that allows it to perform the research and develop of the emerging opportunities by themselves. In this respect, Katila and Chen (2008) indicate that firms having a "head-start" introduce innovative products by seeking knowledge exclusively and by keeping their competitors out. Second, *external ambidexterity* can arise at the level of a firm's alliance portfolio, whereby some alliances are concerned with exploration while others focus on exploitation strategies. Some studies show that firms facing disruptive changes in technologies and/or customer needs overcome obsolescence by opening their search activities extensively (Baden-Fuller et al., 2000; Chesbrough, 2003; Ahuja and Katila, 2004). This idea indicates that the adoption of externally based models of search is a strategy that leads to a technological reposition (Rosenkopf and Nerkar, 2001; Holmqvist, 2004). Finally, *radical ambidexterity* can occur when firms adopt both exploration and exploitation search strategies inside and outside their boundaries. In this case, firms adopt boundary- spanning mechanisms in the simultaneous implementation of their search strategies. Radical ambidexterity is in line with the use of the mixed mode of business and science orientation in R&D proposed by DeSanctis et al., (2002). In this mode, firms extensively integrate the search process rooted in their alliance portfolio with that occurring in corporate units with both a business and science orientation.

By contrast, **specialization** refers to those models of organizational search where firms adopt just one search type at a time, be it exploration or exploitation. Specialization can occur in one of two ways. On the one hand, firms opt for a given search type for any given period, switching from exploration to exploitation search strategies over time. This pattern relies on a punctuated equilibrium in that implementation is *sequential* (Tushman and Anderson, 1986; Gersick, 1991). As suggested by previous research, this happens when exploration interrupts long periods of exploitation. In this setting, new technologies emerge sequentially from exploration search. Some of the new technologies become new paradigms, bringing new opportunities to be subsequently exploited (Henderson and Clark, 1990). On the other hand, organizations may choose to specialize *permanently* in exploration, while others make the same decision in favor of exploitation search (Gupta et al., 2006). For instance, in cases where firms *permanently* specialize in exploitation, the market for new technologies may strike a balance between exploration and exploitation, meeting the basic research needs of such firms with the supply of organizations specialized in exploration, i.e., universities and/or public research centers.

As in the case of ambidexterity, we propose three models of specialization. *Internal specialization* characterizes models of organizational search where firms implement either exploration or exploitation search strategies internally. In the case of temporary or permanent specialization, tangible and/or intangible resources for search activities are concentrated in the firms' technological subunits that focus on a given type of search. Riccaboni and Moliterni (2009) describe two technological regimes, in which some "dedicated biotech companies" tend to specialize in early-research stages mainly targeted to product development (exploitation) while some others do so in the development of general-purposes platform technologies primary targeted to the discovery of new drugs (exploration). Alternatively, *external specialization* means that firms that adopt organizational boundary-spanning mechanisms for their search strategies choose to adopt only one type of strategy externally. In this case, the firm's alliance portfolio comprises external links in which partners' assets align, temporarily or permanently, with either explorative alliances or exploitative alliances. Compared with the external ambidexterity model, external specialization may be regarded as an incremental way of opening the search process of the firm in order to reach a technological reposition.

Finally, *radical specialization* occurs in those settings in which firms combine internal and external specializations. Here again we can distinguish two possible arrangements for this form of implementation. The first corresponds to models of "inter-organizational specialization" as firms utilize the same type of strategy internally as that adopted externally. The second refers to models of "inter-organizational ambidexterity" as firms adopt a different strategy internally from that adopted externally. Although the two models involve a radical specialization (internal and external single implementation), they differ in the way firms combine their search activities. In line with Rosenkopf and Nerkar (2001), inter-organizational specialization places the emphasis on combinations occurring by organizational boundary-spanning, while inter-organizational ambidexterity places the emphasis on combinations occurring by both technological and organizational boundary-spanning.

Diversification, by contrast, involves a situation in which firms combine a simultaneous with a single implementation of strategies across their organizational boundaries. Unlike the other models, diversification means that firms necessarily span their organizational boundaries when combining alternative implementation strategies. Diversification can arise in two situations. *Type I diversification* describes a situation in which firms combine an internal single with an external simultaneous implementation. In this case, search activities are conducted by specialized technological subunits within firms in conjunction with a portfolio comprising exploration and exploitation alliances. Conversely, *type II diversification* occurs when firms choose an internal simultaneous together with an external single implementation. In this setting, the search performed by ambidextrous technological subunits within firms is combined with an alliance portfolio centered on either exploration or exploitation search. While type I diversification is a model of organizational search that joins different forms of external venturing (explorative and exploitative), and in which knowledge creation occurs in a network of external actors, type II diversification of is primary focused on a search process with an internal orientation[6], and in which external searching is rather used for scouting environmental opportunities. Small companies, with a strong portfolio of external venturing, probably lean toward a model of type I diversification, while large companies, with a remarkable tendency to internalize their R&D activities, lean toward a model of type II diversification (Schildt et al., 2005).

Each category in Figure 1 should be interpreted as describing a tendency of a firm to organize its search activities around a particular model. This is the case, since it is almost impossible to observe all the search activities of a firm. Rather, it is more likely to identify the search activities that tend to prevail within the organizational search adopted by the firm for its R&D activities (DeSanctis et al., 2002).

Our typology builds on the findings of Rosenkopf and Nerkar (2001) and on those of Rothaermel and Alexandre (2008) in several ways. In common with these studies, our research recognizes that the knowledge search process is limited by technological and/or organizational boundaries, and highlights the fact that firms can enhance performance by using their combinative capabilities[7]; that is, by combining search strategies with different alignments.

[6] Katila (2002) examines how firms search for knowledge internally, determining the innovative performance consequences associated with a process of internal search.
[7] These capabilities are defined here as the skills of a firm to bring together different streams of knowledge to innovate (Kogut and Zander, 1992; Nerkar, 2003).

However, our approach adds to these studies in the following ways. While Rosenkopf and Nerkar (2001) are concerned with describing boundary-spanning strategies to increase explorative search, our focus is rather on examining models of organizational search that combine exploration with exploitation search. Compared with Rothaermel and Alexandre's study (2008), our research recognizes the existence of alternative forms of organizational search to that considered in the ambidextrous model (i.e., specialized or diversified model). In this way, the current study extends previous research to describe a variety of implementation strategies via which firms may organize exploration and exploitation search.

Drawing on the typology described above, we now examine the innovation consequences associated with each search model and analyze the antecedents to the firms' decision to choose these models.

2.2 Performance implications of firms' search choices

As discussed in Figure 1, firms can conduct their knowledge search by implementing exploration and exploitation strategies in several ways. These models differ in the degree to which firms combine alternative learning sources. Comparatively, models in the upper-right box of Figure 1 are those in which firms combine more learning sources across technological and/or organizational boundaries. Accordingly, we posit that models of organizational search in Figure 1, in which the pursuit of knowledge is carried out by joint search strategies, should be more productive in terms of performance because of the existence of complementarities. This is in line with recent studies in innovation management, which show that firms combining knowledge across these boundaries perform better. For instance, Rosenkopf and Nerkar (2001) find that firms using combined boundary-spanning mechanisms achieve a higher innovative performance in the optical disk industry. For a sample of companies in the robotics industry, Katila and Ahuja (2002) find that the effect of search scope (exploration) on performance is positive, increasing with the level of search depth (exploitation). Likewise, Nerkar and Roberts

(2004) analyze a sample of pharmaceutical companies, showing that distal technological experience and distal market experience positively interact in their relationship with performance. He and Wong (2004) examine a sample of manufacturing firms, finding evidence of a positive interaction between exploration and exploitation activities on firm performance. All these results are consistent with previous research that emphasizes the role of the firm's combinative capabilities in shaping performance (e.g., Kogut and Zander, 1992; Henderson and Cockburn, 1994). Accordingly, in this study we hypothesize that:

Hypothesis 1a: *the adoption of an internal and external single implementation produces complementarities derived from joining exploration and/or exploitation search activities across the firm's organizational boundaries.*

Hypothesis 1b: *the adoption of a single and a simultaneous implementation produces complementarities derived from joining exploration and exploitation search activities across the firm's organizational boundaries.*

Hypothesis 1c: *the adoption of an internal and external simultaneous implementation produces complementarities derived from joining exploration and exploitation search activities across the firm's organizational boundaries.*

2.3 Determinants of firms' search choices

Here, we argue that firms decide how to implement their search activities by considering such factors as their own capabilities and environmental conditions. Below further details are given as to how a number of specific factors affect firms' search choices.

2.3.1 The firm's ACAP

Since the models in Figure 1 combine diverse search activities (i.e., upstream and downstream, internal and external), they will produce different levels of tension in their implementation. In line with discussions in the innovation management literature, in this research we suggest that a firm's ACAP (understood as the ability to value, assimilate, and apply external knowledge, Cohen and Levinthal, 1990), contributes to mitigating these tensions.

As argue below, the firm' ACAP facilitates the integration of varied sources of knowledge resulting from exploration and exploitation search occurring inside and/or outside firms.

A firm's ACAP is widely recognized as constituting a multidimensional concept (Cohen and Levinthal, 1990; Zahra and George, 2002; Todorova and Durisin, 2007). In particular, the approach taken by Zahra and George (2002) is helpful to our present discussion, because it explicitly distinguishes ACAP abilities aligned with upstream innovation activities from those aligned with downstream activities. The first group refers to "potential ACAP" and comprises knowledge acquisition and assimilation abilities, while the second refers to "realized ACAP" and includes knowledge transformation and utilization abilities. Accordingly, we propose that potential ACAP enhances firms' predisposition to adopt exploration search, while realized ACAP increases firms' incentives to conduct exploitation search. In line with Nerkar and Roberts (2004), we suggest that the knowledge that develops together with firms' experience in screening new opportunities and in identifying those with potential applications contributes to forming potential ACAP, which in turn allows firms to adopt more exploration search. Similarly, knowledge that develops together with firms' experience in using new knowledge and in applying current firms' technologies contributes to forming realized ACAP, which also enables firms to implement more exploitation search.

Likewise, when spanning organizational boundaries, a firm's ACAP enables it to combine internal with external knowledge search strategies. As shown by a considerable number of studies, a firm with high levels of ACAP is more willing to open up its innovation model and participate actively in external R&D arrangements (e.g., Arora and Gambardella, 1994; Leiponen, 2005; Laursen and Salter, 2006; Rothaermel and Alexandre, 2008). This is the case as the set of complementary abilities (i.e., potential and realized) that sustains ACAP helps firms to identify and apply external knowledge, putting it into context across their organizational boundaries (Cockburn and Henderson, 1998; Rosenkopf and Nerkar, 2001).

A firm's ACAP is a combinative capability that favors the integration of varied sources of knowledge (Van Den Bosch et al., 1999; Danneels, 2004). This holds true because potential and realized ACAP are complementary to the extent that each is rooted in highly specialized activities along the innovation value chain (Henderson and Clark, 1990; Zahra and George, 2002). This in turn implies that a firm with high levels of ACAP is able to move technologies along this innovation value chain, because a firm's ACAP interconnects a range of diverse abilities in knowledge processing (i.e., potential and realized), favoring in turn the tendency to combine exploration with exploitation search (Rosenkopf and Nerkar, 2001; Katila and Ahuja, 2002; Rothaermel and Alexandre, 2008). Taken together, these arguments indicate that ACAP constitutes an antecedent to a firm's choices regarding which models of organizational search to adopt. Hence, here we hypothesized that:

Hypothesis 2: *the firm's ACAP favours the adoption of models of organizational search in which firms combine exploration and exploitation search across their organizational boundaries.*

2.3.2 Diversified technological opportunities

Technological opportunities refer to the existence of external knowledge that contributes to enhancing firms' technological performance (Winter, 1984; Cohen and Levinthal, 1989; Klevorick et al., 1995). These opportunities can originate from several sources, including universities, public research centers, or suppliers (upstream sources), customers, or clients (downstream sources), or competitors (horizontal sources). Previous studies document differences in the level and type of technological opportunities that firms encounter in a range of industries (e.g., Klevorick et al., 1995; Malerba, 2000; Breschi et al., 2000). In these studies, the diversity of these opportunities is widely recognized as a critical element in characterizing firms' environmental conditions.

Drawing upon this idea that the environmental complexity can determine firms' incentives to engage in learning (Winter, 1984; Cohen and Levinthal, 1990; Anand and Khanna, 2000), we posit that firms respond to a high degree of diversity in their technological opportunities by combining alternative search strategies. From a technological perspective, environments with high diversification oblige firms to handle sources of information resulting from both upstream and downstream activities in knowledge creation (Rothaermel, 2001). While some of these sources comprise a pool of promising ideas, others form a pool of well-established ideas. Under these circumstances, firms face incentives to spread their search effort in exploration and exploitation activities in order to take advantage of the cross-fertilization effects derived from combining diverse ideas (Quintana-Garcia and Benavides-Velasco, 2008). In the case of the first pool, firms are encouraged to adopt more exploration activities to discover and evaluate novel potential applications, while in the second case; firms will tend to adopt more exploitation activities to refine their current applications (Nerkar and Roberts, 2004). In addition, promising ideas may also lead firms to engage in more exploitation in an attempt to transform these ideas into new utilizable knowledge. Similarly, well-established ideas may also lead firms to undertake more exploration, especially in cases in which technological exhaustion is imminent (Ahuja and Katila, 2004). Taken together, these results indicate that diverse technological opportunities push firms to diversify their search strategies by combining exploration with exploitation.

From an organizational perspective, diversity in technological opportunities also leads firms to combine their internal and external search strategies. Diversity in technological opportunities pushes firms to extend their search effort beyond their boundaries in order to enhance learning (Mowery et al., 1996; George et al., 2001; Rosenkopf and Nerkar, 2001). Since the capacity of firms to search for diversified sources of information is limited (Rothaermel, 2001; Laursen and Salter, 2006), they may combine their search activities with those performed by external actors, thus enhancing their capacity to access multiple technological opportunities. As shown in previous studies (e.g., Rosenkopf and Nerkar, 2001; Almeida et al., 2003), inter-organizational R&D collaboration allows firms to accomplish this objective. For instance, R&D alliances allow firms to use the partners' ACAP to build bridges via which diverse technological opportunities move from the environment (i.e., universities, suppliers, and customers) to the location of their problem-solving capabilities. In this process, firms build channels by which varied sources of external knowledge acquire a meaning (McEvily and Zaheer, 1999; Rosenkopf and Almeida, 2003; Zaheer and Bell, 2005, Laursen and Salter, 2006). Accordingly, these arguments indicate that diversity in technological opportunities leads firms to combine their internal and external search strategies. Consequently, it is hypothesized that:

Hypothesis 3: *diversified technological opportunities favours the adoption of models of organizational search in which firms combine exploration and exploitation search across their organizational boundaries.*

2.3.3 Combining a firm's ACAP and its diversified technological opportunities

In this study, we argue that the firm's ACAP and the level of its diversified technological opportunities are self-reinforcing and have interactive effects on the firm's search choices. On the one hand, the exposure of firms to diversified technological opportunities can influence the productivity of their ACAP by preventing major core rigidities (Leonard-Barton, 1992; Quintana-Garcia and Benavides-Velasco, 2008). Diverse technological opportunities often provide knowledge that can help firms articulate much better the abilities that sustain their ACAP. Cockburn and Henderson (1998) illustrate this point for the case of the pharmaceutical industry. They suggest that technological opportunities in the scientific community boost a firm's abilities to recognize and take advantage of upstream developments (i.e., those produced by universities). This occurs because external knowledge diversity leads firms to discover new forms of R&D organization and new links to connect their organizational capabilities together. Therefore, the higher a firm's level of diversified technological opportunities, the wider is the spectrum for enhancing its learning capabilities. On the other hand, the firm's ACAP increases the quantity and/or improves the quality of the knowledge embedded in its technological opportunities (Katila and Ahuja, 2002; Almeida et al., 2003). This comes about because a firm's ACAP comprises problem-solving capabilities required to articulate technological opportunities with its own stock of knowledge (Rosenkopf and Nerkar, 2001). Consequently, the higher the firm's ACAP, the greater are the possibilities it enjoys of turning diversified technological opportunities into useful knowledge for its innovation activities. According to previous arguments, it is hypothesized that:

Hypothesis 4: *the firm's ACAP and the degree of diversification of technological opportunities interact in favouring the adoption of models of organizational search in which firms combine exploration and exploitation search across their organizational boundaries.*

3. Empirical Analysis

In this section, we present the data and statistical methods used in testing the above hypotheses. Thus, we used a sample of Spanish manufacturing companies surveyed in a large-scale dataset. Previous research has tended to examine the link between knowledge search activities and performance for specific sectors, e.g., optical disks (Rosenkopf and Nerkar, 2001), robotics (Katila, 2002; Katila and Ahuja, 2002), pharmaceutical (Nerkar, 2003). Despite the insights provided by these studies, industry-specific characteristics may affect the performance assessment of the firms' search activities. Although recent studies have begun to examine multi-industry samples to study the consequences for innovation of organizational search (e.g., Laursen and Salter, 2006; Rothaermel and Alexandre, 2008), little attention is still given to undertaking an analysis of their antecedents.

The empirical design used in the current study contains two parts: one for analyzing the performance consequences and a second for examining the antecedents of organizational search. The former contains an outcome equation, in which a measure of innovative performance depends on both the firms' search choices and on a set of control variables. The latter includes a set of choice equations, in which search choices depend on a set of explanatory and control variables. As search choices are endogenous variables, we considered a research setting in which performance is determined by firms' search choices, as well as by factors that affect these choices.

3.1 Data

The empirical analysis conducted in this paper draws on the *Technological Innovation Panel*[8] (henceforth, PITEC) conducted by the Spanish National Statistic Institute (INE), in collaboration with the Spanish Science and Technology Foundation (FECYT) and the Foundation for Technological Innovation (COTEC). The PITEC includes data on the technological innovation activities of all the main sectors in the Spanish economy, including services and manufacturing. In particular, it gathers information provided by the *Spanish Community Innovation Survey* (CIS) for the period 2003 to 2006, including new data about the technological profiles of the companies surveyed. Drawing on Rosenberg and Kline's model (1986), the PITEC collects information about the objectives of the innovation process, the sources of novel ideas, the obstacles associated with the innovation process, and an evaluation of the effects produced by innovations. Additionally, it provides new information, for example, about the qualifications held by and the gender of the firms' R&D personnel; outsourcing R&D activities classified by origin and type of partners; and the goals sought by firms' in-house R&D activities. In line with similar surveys elsewhere in Europe (i.e., SPRU survey), the PITEC follows the methodological rules laid down by the Oslo Manual (OECD, 1997)[9].

In order to preserve representativeness, the PITEC comprises four samples. The first included data for large firms (with more than 200 employees), covering 73% of the large firms listed by the Spanish Central Company Directory (DIRCE), while the second included information about firms with intramural R&D expenditures. The third sample comprises firms with fewer than 200 employees that report external R&D, but no intramural R&D expenditures.

[8] The PITEC is available at http://sise.fecyt.es/sise-public-web/

[9] Contributions using data similar to the PITEC include, for example, (Lopez, 2008; Cassiman and Veugelers, 2006; Laursen and Salter, 2006; Reichstein and Salter, 2006; Leiponen, 2005; and Mohnen and Roller, 2005).

Finally, the fourth sample includes firms with fewer than 200 employees that report no innovation expenditures. In the case of the present study, we focus our attention on Spanish manufacturing firms in the PITEC for which complete information is available on their innovative activities for two consecutive periods, 2002-2004 and 2004-2006. As a result, our sample contains 3566 observations for each period. These data include companies whose principal economic activity appears in one of the two-digit manufacturing industries of the "Classification of Economic Activities in the European Community"[10].

3.2 Variables

Since the PITEC data are generated from self-reported information provided by the firms surveyed, the "common method bias" (Podsakoff and Organ, 1986) is a cause of concern. To mitigate this problem, we considered some of the remedies applied in other studies (e.g., Jansen et al., 2006; Rothaermel and Alexandre, 2008). Thus, at every opportunity, we separated the dependent and independent variables by introducing a time lag. In the outcome equation, firm performance refers to the period 2004-2006, while the independent variables refer to the period 2002-2004. Similarly, in the set of choice equations, search choices refer to the period 2004-2006, while the remaining independent variables refer to the period 2002-2004. The two-year time lag used here is in line with previous studies based on similar samples (e.g., He and Wong, 2004; Jansen et al., 2006; Rothaermel and Alexandre, 2008). Nonetheless, in the outcome equation, performance and search choices refer to the same period, and here probably, the same respondents reported both. Despite this fact, they were obtained from different response formats, which help to mitigate the common method bias (Podsakoff et al., 2003).

3.2.1 Dependent variables

Performance

[10] This is equivalent to the International Standard Industrial Classification (ISIC).

In the first part of the model, the outcome refers to a given measure of a firm's innovative performance. Since innovative performance is multidimensional (He and Wong, 2004; Sidhu et al., 2007; Rothaermel and Alexandre, 2008), we characterized it by using the reported evaluations provided by the firms surveyed regarding the effects derived from their innovations. On a four-point scale, they rated the extent to which their innovations in the period 2004 to 2006 had had a positive impact on the following aspects: (1) expansion of their market share, (2) improvement in the quality of their products, (3) increase in their product range, (4) reduction in average labor costs, (5) improvement in production flexibility, (6) increase in production capacity, (7) reduction in average costs of raw materials and energy, (8) reduction in the environmental impact of their production, and (9) greater compliance with norms and regulations. For each of these aspects, we awarded a value of 1 if the firm in question rated the effect as strongly-important and 0 otherwise. Subsequently, we added the resulting codified variables so that each firm received 0 when its innovations had no impact and 9 when they were considered to have the maximum impact. This construct has a satisfactory degree of internal consistency (Cronbach's alpha = 0.74).

Our measure of a firm's innovative performance provides a complementary approach to characterizing the outcomes derived from firms' search activities. One advantage of this measure is that it is not limited exclusively to codified forms of knowledge (i.e., patented inventions). Previous studies on innovation usually draw on patent data to characterize outcomes produced by firms' problem-solving capabilities (e.g., Rosenkopf and Nerkar, 2001; Katila and Ahuja, 2002). Despite their suitability for tracking knowledge creation, patents do not necessarily codify the entire knowledge generated by search activities (Laursen and Salter, 2006; Sidhu et al., 2007). A firm's patenting behavior may rather be a consequence of other strategies, such as, preventing possible hold-up problems in the market for new technologies, or blocking a competitor's entry (Gonzalez, 2006). Our measure is also an alternative to other studies in which sales attributable to new products characterize innovative performance (e.g., Cassiman and Veugelers, 2006; Laursen and Salter, 2006). Although this measure correlates with both patented and non-patented knowledge, it may overemphasize the effects of search activities related to product innovation, and understate those attributed to process innovation. We argue that our measure avoids this limitation in that it includes an appraisal of the effects derived from both types of search (product and process innovation).

Firms' search choices

In the set of choice equations, combinations of varied search strategies represent alternative models of organizational search. In order to define the range of firms' search choices, we first need to characterize the exploration and exploitation search occurring inside and outside the firms' boundaries. We focused specifically on search strategies associated with the technological innovation activities conducted by the firms between 2004 and 2006. To this end, we used information from the PITEC concerning the objectives set by firms' intramural R&D. In the case of internal search strategies, we built on Rothaermel and Alexandre (2008), and used firms' expenditure on basic research as a proxy for exploration search and that dedicated to technological development as a proxy for exploitation search. In the PITEC, expenditure on basic research refers to that addressed explicitly to the pursuit of new knowledge but which does not necessarily lead to particular applications, while expenditure on technological development refers to that addressed to the pursuit of novel applications of existing knowledge that improve materials, products and/or technologies. In each case, we built a dummy so that a value of 1 is awarded when firms reported positive expenditure on the search activity in question. In the case of external search strategies, we followed George et al., (2001), and used firms' R&D alliances as a proxy for exploration search, and firms' R&D outsourcing activities as a proxy for exploitation search. In the PITEC, R&D alliances define agreements in which firms actively pursue innovative activities, though these are not necessarily intended to yield profits. By contrast, R&D outsourcing activities refer to situations in which firms subcontract R&D services in the market for technologies to leverage their own R&D activities. Similarly, we built a dummy for each case so that a value of 1 is awarded when firms participate in the external R&D link under consideration.

From these dummies, we characterized alternative ways of conducting the organizational search. Table 1 presents a definition of the models described by Figure 1 in terms of their search strategies. The first column contains nine exclusive categories, including all possible combinations by which firms might implement their search strategies. From these combinations, we built a multinomial choice variable to characterize a firm's implementation strategies. The second column identifies models of organizational search for each exclusive category. Finally, the last column shows the set of observed search strategies used in defining each model.

[Insert Table 1 here]

3.2.2 Independent variables

The firms' absorptive capacity

In line with Veugelers and Cassiman (1999), we used the surveyed firms' evaluations of the importance attached to internal sources of information in developing their innovation activities as our proxy for absorptive capacity (ACAP). On a four-point scale, firms evaluated information sources that originated from their own departments, employees and divisions between 2002 and 2004. We assume that firms reporting a high indicator have a high ACAP, since they were able to move information from its locus of origin to the sites of problem-solving capabilities. This reveals the firms' capacity to identify relevant information and apply it to the solving of problems. Accordingly, firms that are able to use internal information successfully for their innovation activities should be better prepared to reproduce this experience in similar contexts (i.e., from intra-organizational to inter-organizational contexts).

Diversified technological opportunities

We employed PITEC data to determine the use made of external sources of information in the firms' innovation processes. The firms surveyed specified the extent to which they used ten different sources[11]. In line with Cohen and Levinthal (1989), these sources are seen as representing technological opportunities in that they characterize available information that might contribute to enhancing the firms' technological performance. In order to determine the degree of diversification of technological opportunities, we proceeded as follows. First, we conducted an exploratory factor analysis in order to classify the external sources evaluated by firms[12]. As a result, we identified three clusters: the first comprised sources of information related to institutions (e.g., universities and public research centers), the second was made up of sources originating from other firms (e.g., competitors and suppliers), and the third of sources related to formal forms of knowledge (e.g., conferences and journals). Second, we built dummies for each of the ten sources under evaluation. Each dummy takes a value of 1 when the firms stated that they used the source in question. We also added up the previous dummies corresponding to each cluster. Finally, we used a measure of diversity to define the degree of diversification of the firms' technological opportunities. In line with other studies on innovation (e.g., Powell et al., 1996; Ahuja and Katila, 2004), we applied Blau's index (1977) in measuring diversification: $T_i = 1 - \sum_{k=1}^{3} \left(\frac{c_k}{C_i} \right)^2$. In this context, c_k represents the number of sources in cluster "k" used by firm "i", while C_i denotes the total number of sources used by firm "i".

Control variables

The firms' patenting capabilities may also affect their organizational search choices. Firms with these capabilities may be more readily disposed to implement internal and external search activities jointly, since they are able to avoid any leakage of strategic information when interacting with external actors. Likewise, a firm with patenting capabilities can be expected to

[11] Sources under consideration include information arising from (1) suppliers, (2) customers, (3) competitors, (4) consulting firms and/or private research centers, (5) universities, (6) public research centers, (7) technological centers, (8) conferences, (9) publications and journals, and (10) professional associations.

[12] Not shown here for reasons of space, but available from the author upon request.

start exploiting the benefits derived from its innovation activities at an earlier date (March, 1991). This is the case as patents indicate that the firm was able to transform its "inventions" into "technologies" (Katila, 2002). To control for the effect of patenting on organizational search choices and on firms' innovative performance, we included in the analysis a binary variable (*Patent application*), which is given a value of 1 when firms stated that they had applied for patents in the period 2002-2004. One factor that is often identified as constituting a point of difference in the way firms combine their innovative activities is the managers' perception of the constraints that might impede innovations (Athey and Stern, 1998; Veugelers and Cassiman, 1999; Lopez, 2008). In order to control for this aspect, we included a four-point scale variable (*Cost of innovation*) that reflects self-reported assessment by firms concerning the importance of the costs of innovation activities as a factor inhibiting their execution for the period 2002-2004.

Search activities and their consequences may vary in line with the scale of the firms' operations (Winter, 1984; Katila and Ahuja, 2002; Almeida et al., 2003). Therefore, we added to the model a binary variable (*Firm size*), given a value of 1 when firms reported having more than 200 employees. Additionally, previous research shows that firms' willingness to implement exploration and exploitation search across their boundaries may depend on whether they form part of a multinational group (Veugelers, 1997; Nerkar and Roberts, 2004 Vanhaverbeke et al., forthcoming). To control for this feature, we included in the analysis a binary variable (*Business group affiliation*), given a value of 1 when firms reported that they belonged to a multinational group. Finally, we can expect firms acting in more technologically dynamic environments to differ in their choices regarding search activities and in innovative performance, compared with those that operate in less dynamic technological environments (Ahuja and Katila, 2004; Jansen et al., 2006). We controlled for this fact by incorporating two binary variables within the model. In line with the OECD (1997), we classified firms according to the degree of technological intensity in the industries in which they operate. Next, we built a dummy given a value of 1 when firms operate in a sector classified as high-tech industries (*High-tech sector*), and another coded with 1 when firms operate in a sector classified as low-tech (*Low-tech sector*). With these dummies, we aim to control for other aspects of the technological regime not included in the analysis (Veugelers and Cassiman, 1999).

Exclusion Restrictions

In order to guarantee the robustness of the identification, we added variables to the choice equations that were not included in the outcome equation. Given the difficulties that have been documented in finding appropriate instrumental variables in surveys similar to the PITEC (e.g., Cassiman and Veugelers, 2006), we adopted some of the recommendations made by previous studies of strategy and performance (e.g., Athey and Stern, 1998; Hamilton and Nickerson, 2003). Specifically, we included two variables reflecting regulation and governmental policies that may differ across industries and that may affect search choices. Thus, we added, on the one hand, the number of public programs available for financing R&D activities (*Financing sources*)[13] and, on the other, the number of markets (regions) to which firms supply their products (*Market scope*)[14]. Some studies consider the first variable to be a critical element, modifying the incentives of Spanish manufacturing companies engaged in R&D activities (Bayona et al., 2001). The second variable seeks to characterize differences in trade policy and institutional characteristics that may affect the incentives of firms to supply their products to varied markets (regions). In order to allow for differences across industries, we followed previous studies on innovation (e.g., Cassiman and Veugelers, 2002; Lopez, 2008), and measured both variables at the industry level, defined at two-digit NACE.

Table 2 displays descriptive statistics for the variables described above. In addition, Table A1 in the appendix shows the corresponding bivariate correlation matrix.

[Insert Table 2 here]

[13] These financing programs include local, governmental and European Union programs, as well as other EU programs.

[14] Firms can supply products to local, national and European markets, as well as markets in other countries.

3.3 Statistical Methods

Since our measure of firm performance is a non-negative integer variable (number of times that innovations are perceived as having a strongly positive effect) and the firms' search choices are viewed as a multinomial variable, we implemented the Deb and Trivedi model (2006) in the subsequent empirical analysis. This is a model of treatment (firms' search choices) and outcome (performance) with selection, in which the treatment is endogenous. Although the attention of this model is specifically focused on the effect of an endogenous treatment variable on outcome, we can harness the fact that this model also provides us with a characterization of the generating process of the treatment. This is informative about the role of factors in determining firms' search choices.

In the outcome equation, the observed *Performance* for firm "i" is denoted by y_i. It is assumed that values for this variable follow a negative binomial structure, in which the expected outcome is described by:

$$E\left(y_i \mid \mathbf{x}_i, d_{ji}, l_{ji}\right) = \mathbf{x}_i'\beta + \sum_j \gamma_j d_{ji} + \sum_j \lambda_j l_{ij} \qquad (1)$$

where $\mathbf{x_i}$ is a vector of exogenous variables, d_{ji} corresponds to binary variables representing the observed firm's search choices, where j denotes the set of search models described by Table 2. Alternatively, β and γ_j are parameters associated with the exogenous variables and firm choice variables, respectively. Finally, ℓ_{ji} denote latent factors that represent unobserved characteristics concerning firm i's choice of model of organizational search of type j. The λ_j represents factor loadings associated with the latent factors.

Alternatively, choice equations characterize the probability that firm "i" chooses the model of organizational search "j". Specifically, it is assumed that these probabilities are described by a mixed multinomial logit structure given as follows:

$$\Pr\left(d_{ji} = 1,|\, \mathbf{z}_i, l_{ji}\right) = \frac{\exp\left(\mathbf{z}_i^{'}\alpha_j + \delta_j l_{ji}\right)}{\sum_{k=0}^{J}\exp\left(\mathbf{z}_i^{'}\alpha_j + \delta_k l_{ki}\right)} \tag{2}$$

where $\mathbf{z}_i$ represents exogenous covariates while α_j are the corresponding parameters. As in the outcome equation, ℓ_{ji} are latent factors and δ_j are the corresponding factor loadings.

Whereas equation (1) describes innovative performance as a response to firms' search choices, we can test for the existence of complementarities by using the notion of supermodularity (Athey and Stern, 1998; Mohnen and Roller, 2005). To this end, we first defined the conditions for which innovative performance in (1) is supermodular in the space of the firms' implementation strategies (See Table 1). By using estimates of γ_j, these conditions are as follows:

Supermodularity on internal and external single implementation	$\gamma_{\text{type 5}} - \gamma_{\text{type 2}} > \gamma_{\text{type 4}} - \gamma_{\text{type 1}}$	(3.1)
Supermodularity on internal single and external simultaneous implementation	$\gamma_{\text{type 6}} - \gamma_{\text{type 3}} > \gamma_{\text{type 4}} - \gamma_{\text{type 1}}$	(3.2)
Supermodularity on internal simultaneous and external single implementation	$\gamma_{\text{type 8}} - \gamma_{\text{type 2}} > \gamma_{\text{type 7}} - \gamma_{\text{type 1}}$	(3.3)
Supermodularity on internal and external simultaneous implementation	$\gamma_{\text{type 9}} - \gamma_{\text{type 3}} > \gamma_{\text{type 7}} - \gamma_{\text{type 1}}$	(3.4)

The supermodularity of a firm's innovative performance implies the existence of complementarities between alternative implementation strategies, since their combined adoption raises innovative performance higher than if they were adopted individually. In order to test for complementarities, we assumed that firms self-select the search model that represents the best fit with their learning and environmental conditions. In the context of this study, choice equations (2) characterize the process of self-selection by considering the observable (i.e., *the firm's ACAP*) and unobservable factors (given by ℓ_{ji}) that affect firms' search choices. In this way, we correct for endogeneity while estimating parameters γ_j, which has been described as a recurring problem in previous studies on complementarities (e.g., Athey and Stern, 1998; Leiponen, 2005; Miravete and Pernias, 2006; Cassiman and Veugelers, 2006).

4. Results

Table 3 shows the results for the estimates of both the outcome (first column) and choice equations (the remaining columns). Estimates were carried out using the Simulated Maximum Likelihood Method with 2000 simulation draws, based upon Halton sequences (Deb and Trivedi, 2006). The outcome equation was used to test for complementarities while the choice equations were used to examine the factor determining firms' search choices. In order to avoid potential multicollinearity, we mean centered the explanatory variables - *the firm's ACAP* and *diversified technological opportunities* - before creating their product interaction term (Aiken et al., 1991). As a starting point, we used the same group of independent variables for all the equations[15]. This means that, in the outcome equation, we included *the firm's ACAP*, *diversified technological opportunities* and their interaction effects as additional control variables. As recommended by Deb and Trivedi (2006), we also added exclusive restrictions to our choice equations. Although this was not strictly necessary in this case[16], the inclusion of variables should provide a more robust identification.

Furthermore, we estimated a conventional multinomial logit model for the choice equations, and tested for the joint significance of the instruments in that model. By using the likelihood ratio, we found evidence that the fit of this model improves on including the

[15] Not shown here for reasons of space, but available from the author upon request.
[16] Deb and Trivedi (2006) point out that the parameters of the model are identified through nonlinear functional forms even when all the variables in the choice equations are included in the outcome equation.

instruments (p-value smaller than 0.001). This indicates that these instruments are statistically suitable identifiers (Deb and Trivedi, 2006). We also confirmed that the instrumental variables had no explanatory power in the outcome equation. Finally, we investigated the independence of the irrelevant alternative (IIA) hypothesis by using both the Hausman and Small-Hsiao tests. In both cases, the results indicate that the IIA assumption is not violated[17].

[Insert Table 3 here]

Innovation consequences of organizational search

We observe that models of organization search in which firms combine explorative with exploitative search activities (inside and/or outside their boundaries) have a positive and significant impact on firms' innovation performance. As expected, given that radical ambidexterity is the model that combines the largest number of search strategies, it is also the model with the most significant impact on innovation performance. Conversely, the models based on specialization, be it internal or external, are not statistically significant determiners of performance. By using the Wald test, we further conducted a comparison between the models in terms of their effects on performance. We found that the adoption of radical ambidexterity has a statistically greater impact on performance than that associated with the adoption of radical specialization (p-value smaller than 0.001). We also found that the adoption of a type I diversification has a statistically greater effect on performance than that attributed to the adoption of a type II diversification (p-value = 0.077). Finally, we observe that the null hypothesis establishing no differences between external and internal ambidexterity in terms of their effects on performance cannot be rejected at conventional levels. In order to identify any synergetic effects arising out of the combined adoption of implementation strategies (single and simultaneous), our next step is to test for the existence of complementarities.

[17] Not shown here for reasons of space, but available from the author upon request.

In line with Athey and Stern (1998), we considered inequalities (3.1)-(3.4) as restrictions to be met in order for a firm's innovative performance to be supermodular in the space of firms' search choices. To this end, we applied the procedure developed by Kodde and Palm (1986)[18]. Accordingly, each restriction in Table 3 can be defined under the null or under the alternative hypothesis (Kodde and Ritzen, 1988). Thus, the test for complementarities has a *strict equality* under the null hypothesis (interpreted here as a signal of no interaction), and a *strict inequality* under the alternative (viewed here as evidence for strict supermodularity). We took each restriction at a time, considering the test for supermodularity to be a one-sided test. The rejection of the null in favor of the alternative is interpreted here as evidence of the existence of supermodularity in the firms' innovative performance in the pair of implementation strategies under consideration (see Table 3). When this is the case, we conclude the existence of complementarities.

Without losing generality, we normalized the coefficient $\gamma_{\text{type 1}}$ to zero as in other empirical studies on complementarities (e.g., Leiponen, 2005; Belderbos, et al., 2006). The results for the test of complementarities are as follows. We find an interaction effect associated with the joint adoption of internal and external single implementation. That is, the null hypothesis establishing the equality, $\gamma_{\text{type 5}} - \gamma_{\text{type 2}} - \gamma_{\text{type 4}} = 0$, is rejected at the 10% significance level (p-value = 0.052) in favor of the alternative, $\gamma_{\text{type 5}} - \gamma_{\text{type 2}} - \gamma_{\text{type 4}} > 0$, defining the restriction that underpins supermodularity. This shows that a single implementation in one search type, *both* internally and externally, allows firms to yield additional returns in terms of innovative performance. Furthermore, in order to identify differences in complementarities associated with differences in the ways that firms combine their search strategies, we divided the firms into two groups using a radical specialization. The first group comprises firms that adopt an inter-organizational specialization, while the second includes

[18] Although Kodde and Palm's (1986) procedure refers to combinations of several equality and inequality restrictions, our setting is, in fact, a particular instance of their general framework.

firms that use an inter-organizational ambidexterity. We then compared the complementarities associated with each group[19]. We found that the null hypothesis is rejected at the 10% significance level (with a p-value of 0.071 for the first case, and a p-value of 0.085 for the second) in favor of the alternative sustaining supermodularity. Interestingly, the presence of complementarities, irrespective of the way firms combine internal and external specialized search strategies, suggests that the organizational dimension, rather than the technological dimension, is the main generator of such complementarities.

For the remaining inequalities, (3.2)-(3.4), we find that the null hypothesis cannot be rejected at conventional levels. Accordingly, we do not find support for the hypothesis of complementarity in these cases. The lack of synergetic effects might be explained by the fact that, in a simultaneous implementation, the costs override the benefits derived from aligning opposing search strategies. This result is in line with Rothaermel and Alexandre (2008), who show that, after a particular threshold is reached, the returns of ambidextrous search models diminish. Likewise, other studies also suggest that the returns derived from multiple search strategies fall because of the limited capacity of managers to allocate their attention and resources to several search activities (e.g., Rothaermel, 2001; Laursen and Salter, 2006).

The results corresponding to the control variables are as follows. In line with George et al., (2001), the estimates for the firms' ACAP are positive and statistically significant, indicating that knowledge-processing capabilities have a direct impact on performance. We also found that the parameter *diversified technological opportunities* is positive and statistically significant in determining performance. In line with Laursen and Salter (2006), this shows that external sources of knowledge complement traditional explanatory variables in explaining performance. Furthermore, we observe that the interaction effect of previous factors is highly significant statistically in their relationship with performance. Finally, we observe that the

[19] Regression results for these cases are not shown here for reasons of space, but they are available from the author upon request.

parameter for *cost of innovation* is positive and statistically significant. This result is consistent with Veugelers and Cassiman (1999), who argue that managers' perception of obstacles impeding innovation captures their awareness of these obstacles rather than the effectiveness of these obstacles in inhibiting innovations. This argument is consistent with other studies showing that the firms' assessment of factors affecting innovations (motivators and inhibitors) is an important element of the firms' technology management with an impact on their degree of innovativeness (Kale et al., 2002; Huergo, 2006).

The antecedents of organizational search

Based on the results contained in Table 3, Figure 2 describes the differences between the models of organizational search as a function of the firms' ACAP and their level of diversified technological opportunities. We observe that the ACAP tends to be positively associated with those models in which firms combine exploration and exploitation search activities. In three instances, the ACAP relates to models involving combinations across the firms' boundaries. In the remaining cases, the ACAP is associated with internal search models, be they ambidextrous or specialized. These results lend partial support to the hypothesis that the firm's ACAP contributes to enhancing its possibilities of combining search activities. In the case of diversified technological opportunities, it seems that this variable is strongly associated with models centered on radical ambidexterity and diversification (types I and II). To a lesser degree, this variable is also associated with models in which firms combine external search activities (external ambidexterity) and with those in which firms combine specialized search activities (radical specialization). Despite its statistical significance, the effect of this variable is not as marked in those models in which firms use only one search strategy (i.e., no combination of search strategies). These results indicate that the diversity of technological opportunities can account for the tendency of firms to combine exploration and exploitation search activities across their boundaries. Finally, the interaction between the firm's ACAP and diversified opportunities is strongly associated with models that combine the largest number of search strategies. Evidence for this lies in the fact that the effect of diversified technological opportunities on the probability of choosing a model based on radical ambidexterity or diversification (types I and II) increases with the level of the firm's ACAP.

[Insert Figure 2 here]

Our results regarding the estimates of the control variables are as follows. We found that firms with patent applications are more likely to combine internal and external search activities. This is consistent with the idea that firms with the capabilities to protect their innovations are more willing to conduct their search in inter-organizational environments. We observe that firms who see costs as an obstacle impeding innovations are less likely to choose a model based on a single internal implementation. This may be related to the fact that the opportunity costs of using models with an internal specialization (i.e., not experiencing economies of scope) may prevent firms from organizing their search strategies by using these models. Alternatively, firms affiliated to a multinational group are more likely to adopt models in which firms combine internal with external search activities (radical ambidexterity and type I diversification) or models in which firms open up their search strategies by including external ambidexterity. By contrast, firms affiliated with multinationals are less likely to adopt an internal ambidextrous model. We also observe that firms operating in low-tech sectors are less likely to choose models comprising internal search activities, such as internal specialization, radical specialization or internal ambidexterity. Alternatively, firms operating in high-tech sectors are more likely to adopt models based on external ambidexterity. Finally, with regard to industrial level variables, we observe that sources for financing R&D activities determine positively the probability of choosing a model in which internal and external search activities are combined.

5. Concluding remarks

As firms pursue knowledge inside and outside their organizational boundaries, we have examined how they go about selecting their search strategies, based on March's (1991) dichotomy of exploration and exploitation. Specifically, we have argued that firms choose from among a range of implementation strategies that combine search activities in a variety of ways. Based on the overlap in firms' choices of internal and external search strategies, we have presented a new typology that recognizes three generic models of organizational search: ambidextrous, specialized, and diversified implementation models. We have then analyzed the respective performances of these models and examined the drivers of firms' search choices.

Our findings regarding the performance of these knowledge search models make the following contributions to the innovation management literature. An empirical comparison of the capacity of the models in our typology to generate complementarities shows that the synchronized implementation of specialized search strategies across firms' organizational boundaries has synergetic effects on performance, indicating the existence of complementarities. This conclusion holds regardless of how firms choose to combine their search strategies across their boundaries, i.e., by adopting either inter-organizational specialization or inter-organizational ambidexterity. In line with Rosenkopf and Nerkar (2001), our result demonstrates that the search activities being conducted in an inter-organizational context are an important source of complementarities. By contrast, our data do not support the hypothesis identifying the presence of complementarities in the case of other implementation arrangements. This reflects the fact that the cost of implementing ambidextrous search models outweighs any associated benefits. While any comparison of this nature should be treated with caution, our results do suggest that differences in the generation of complementarities may well correspond to differences in the way firms strike a balance in their adoption of search strategies that differ in their technological profiles (exploration vs. exploitation) and/or in their organizational forms (internal vs. external).

This paper has also provided new evidence concerning the role of firms' ACAP, their diversity in technological opportunities and the interaction of the two as drivers of their decisions to adopt a particular model of organizational search. As we allow for self-selection, we present an alternative method for characterizing the impact of these drivers on firms' innovative performances. In particular, our results indicate that these factors result in firms self-selecting models of organizational search that combine several search strategies (in particular models based upon radical ambidexterity, and types I and II diversification).

The results of the current research are subject to several limitations but, at the same time, new avenues of future research are opened up. Although conceived as panel data, our data essentially present a cross-sectional design. This prevents us from undertaking a dynamic analysis of the evolution in the elements comprising the organizational search of firms, imposing limitations on the scope of our research. More research is needed in order to characterize the influence of path-dependent decisions on current firm choices regarding their search strategies. Closely related to this, and constituting an attractive avenue of further research, is the question as to whether firms organize their search strategies by adopting the same model type over time, or rather by sequentially switching to alternative models. Research into these aspects might contribute to the literature by advancing our understanding of how previous search patterns determine firms' future choices of organizational search models, and of how firms achieve a balance in their search strategies over time.

Likewise, more research is required in order to examine how changes in the configuration of firms' technological opportunities can affect their choices regarding search strategies, and subsequently, their innovative performance. This aspect is important for understanding firms' incentives to adopt ambidextrous or specialized search models. For instance, Laursen and Salter (2006) document this question by showing that a firm's search strategies depend on the degree of novelty shown by its innovations. They argue that this relates to the degree of diversity shown by its technological opportunities. While incipient innovations tend to be associated with a narrow range of external sources of knowledge, mature innovations tend to be associated with a much broader range. This shows that the dynamic that underpins innovations determines the degree of diversity in a firm's technological opportunities, which in turn can affect a firm's choices regarding its search strategies.

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Figure 1
Models of organizational search

External Balance			
Simultaneous	External Ambidexterity	Type I Diversification	Radical Ambidexterity
Single	External Specialization	Radical Specialization	Type II Diversification
No Implementation	No search	Internal Specialization	Internal Ambidexterity
	No Implementation	**Single**	**Simultaneous**

Internal Balance

Table 1
Exclusive categories that define models of organizational search

Exclusive Combinations	Models	Search Strategies
No implementation	No adoption	No search
External single implementation	External Specialization	Either R&D alliances or R&D outsourcing
External simultaneous implementation	External Ambidexterity	Both R&D alliances and R&D outsourcing
Internal single implementation	Internal Specialization	Expenditure on either basic research or development
Internal with external single implementation	Radical Specialization	Expenditure on either basic research or development, and either R&D alliances or R&D outsourcing
Internal simultaneous and external single implementation	Type I Diversification	Expenditure on both basic research and development, and either R&D alliances or R&D outsourcing
Internal simultaneous implementation	Internal Ambidexterity	Expenditure on both basic research and development
Internal single with external simultaneous implementation	Type II Diversification	Both R&D alliances and R&D outsourcing, along with expenditure on either basic research or development
Internal with external simultaneous implementation	Radical Ambidexterity	Expenditure on both basic research and development, along with both R&D alliances and R&D outsourcing

Table 2
Descriptive statistics

Variable	Mean	S.D.	Min	Max
Performance	2.49	2.23	0	9
External specialization	0.06	0.24	0	1
External ambidexterity	0.02	0.15	0	1
Internal specialization	0.25	0.43	0	1
Radical specialization	0.17	0.37	0	1
Type I diversification	0.12	0.32	0	1
Internal ambidexterity	0.09	0.26	0	1
Type II diversification	0.07	0.26	0	1
Radical ambidexterity	0.05	0.23	0	1
The firm's ACAP	0.80	0.27	0	1
Diversified technological opportunities	0.51	0.21	0	0.67
Patent Applications	0.24	0.43	0	1
Cost as an obstacle for innovations	0.61	0.34	0	1
Business group affiliation	0.37	0.48	0	1
Firm size	0.19	0.40	0	1
Low-tech sector	0.09	0.29	0	1
High-tech sector	0.09	0.29	0	1
Financing sources*	0.56	0.13	0.21	1.5
Market scope*	3.13	0.29	1.53	3.53

* Measured at the industry level (defined at two-digit NACE).

Table 3
Regression results for the choice on searching and for firm innovative performance

Independent variables	Performance	External specialization	External ambidexterity	Internal specialization	Radical specialization	Diversification type I	Internal ambidexterity	Diversification type II	Radical ambidexterity
External specialization	0.067 (0.057)								
External ambidexterity	0.162† (0.045)								
Internal specialization	0.059 (0.040)								
Radical specialization	0.187*** (0.062)								
Diversification, type I	0.287† (0.032)								
Internal ambidexterity	0.161 (0.105)								
Diversification , type II	0.238† (0.034)								
Radical ambidexterity	0.383† (0.038)								
The firm's ACAP	0.441† (0.081)	0.121 (0.553)	0.829 (0.594)	1.099* (0.641)	0.876 (0.658)	1.051** (0.502)	1.177** (0.541)	1.058* (0.546)	1.056** (0.505)
Diversified technological opportunities	0.352*** (0.111)	0.834† (0.201)	1.265† (0.340)	0.291*** (0.111)	1.174† (0.143)	3.553† (0.231)	0.790† (0.225)	2.758† (0.314)	3.897† (0.237)
ACAP x diversified technological opportunities	0.584† (0.103)	0.106 (1.175)	-0.153 (3.061)	1.261 (1.277)	1.093 (1.117)	4.622† (0.641)	0.536 (0.976)	2.179*** (0.756)	3.967** (1.805)
Patent application	0.020 (0.020)	-0.243 (0.284)	0.234 (0.172)	0.120 (0.088)	0.368** (0.145)	0.542** (0.258)	0.672† (0.097)	0.999† (0.170)	1.094† (0.137)

Independent variables (Cont.)	Performance	External specialization	External ambidexterity	Internal specialization	Radical specialization	Diversification type I	Internal ambidexterity	Diversification type II	Radical ambidexterity
Cost as an obstacle for innovation	0.059** (0.029)	-0.038 (0.150)	-0.638 (0.467)	-0.316* (0.171)	-0.369** (0.187)	-0.338 (0.210)	-0.038 (0.182)	-0.054 (0.162)	-0.169 (0.221)
Business group affiliation	0.018 (0.029)	0.485 (0.368)	0.745** (0.290)	0.045 (0.187)	0.374 (0.282)	0.660*** (0.237)	-0.372** (0.180)	0.179 (0.183)	0.876† (0.181)
Firm size	0.027 (0.042)	0.124 (0.265)	0.271 (0.200)	-0.774 (0.748)	-0.141 (0.765)	0.494 (0.762)	-0.415 (0.794)	0.059 (0.789)	0.290 (0.792)
Low-tech sector	-0.035 (0.029)	0.090 (0.229)	-0.369 (0.232)	-0.336*** (0.098)	-0.320** (0.101)	-0.418 (0.333)	-0.089 (0.060)	-0.049 (0.113)	-0.055 (0.293)
High-tech sector	0.012 (0.017)	0.100 (0.156)	0.430† (0.112)	-0.151 (0.201)	-0.068 (0.181)	-0.078 (0.226)	0.161 (0.193)	0.317 (0.289)	0.167 (0.385)
Industrial level for financing sources		-1.065*** (0.392)	1.858 (1.600)	0.886* (0.505)	1.693† (0.275)	2.903† (0.363)	0.302 (0.726)	2.147† (0.311)	2.268† (0.700)
Industrial level for market scope		0.447 (0.365)	0.225 (0.766)	0.443** (0.217)	0.065 (0.239)	0.112 (0.521)	0.350 (0.406)	0.525 (0.365)	0.198 (0.263)
Constant	0.681† (0.042)	-1.962 (1.276)	-3.553 (2.453)	-0.920 (0.947)	-0.734 (1.158)	-2.429 (1.902)	-1.581 (1.654)	-3.909** (1.677)	-3.628*** (1.361)
α (alpha)	0.433 (0.037)								
Log-pseudo likelihood	-14336.282								
Goodness of fit	$\chi^2(105) = 714.3$***								
Nº (observations)	3566								

Robust standard deviation in brackets. * p < 0.10; ** p < 0.05; *** p < 0.01; † p < 0.001.

Figure 2
Models of organizational search classified by the firms' ACAP and diversified technological opportunities

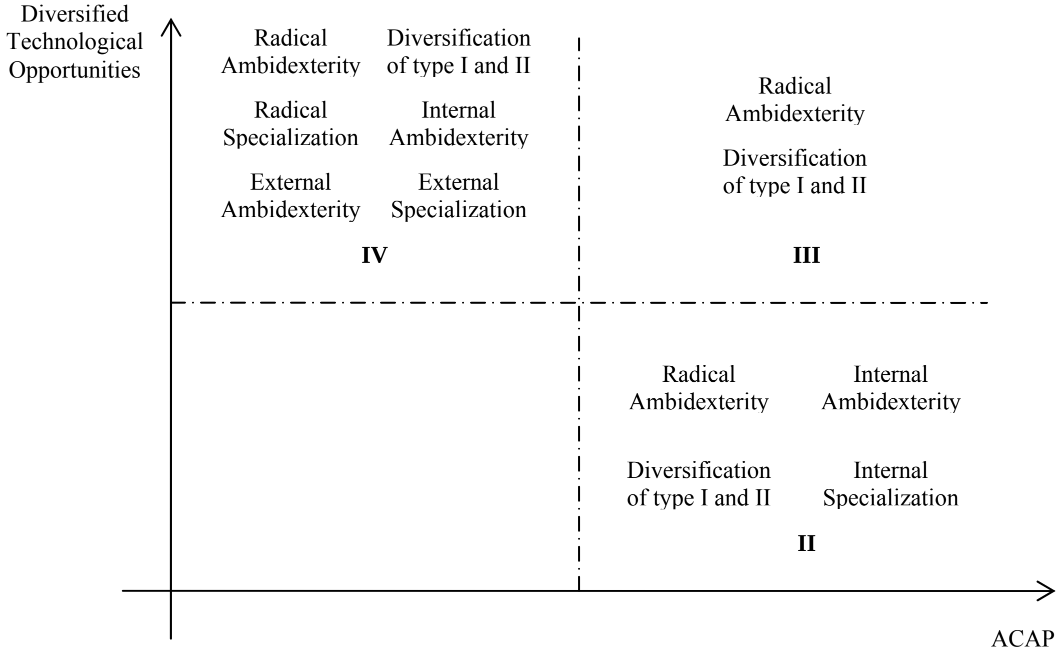

Table A1
Correlation Matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	External specialization	1.000															
2	External ambidexterity	-0.044	1.000														
3	Internal specialization	-0.138	-0.093	1.000													
4	Radical specialization	-0.119	-0.081	-0.252	1.000												
5	Type I diversification	-0.102	-0.069	-0.216	-0.187	1.000											
6	Internal ambidexterity	-0.086	-0.058	-0.183	-0.158	-0.136	1.000										
7	Type II diversification	-0.079	-0.053	-0.166	-0.144	-0.123	-0.104	1.000									
8	Radical ambidexterity	-0.070	-0.047	-0.148	-0.128	-0.110	-0.093	-0.084	1.000								
9	The firm's ACAP	-0.051	0.011	-0.009	0.003	0.054	0.019	0.039	0.051	1.000							
10	Diversified tech-opportunities	-0.026	0.006	-0.100	-0.001	0.117	-0.015	0.081	0.100	0.254	1.000						
11	ACAP x diversified tech-opportunities	-0.004	-0.017	0.007	-0.011	0.017	-0.023	-0.011	0.001	-0.343	-0.286	1.000					
12	Patent application	-0.066	-0.009	-0.071	-0.012	0.053	0.022	0.087	0.105	0.101	0.125	0.010	1.000				
13	Cost of innovation	0.001	-0.028	-0.007	-0.020	-0.013	0.028	0.023	0.004	0.025	0.105	-0.044	-0.004	1.000			
14	Business group affiliation	0.019	0.053	-0.097	0.017	0.122	-0.104	0.005	0.106	0.107	0.072	0.005	0.076	-0.109	1.000		
15	Firm size	0.024	0.042	-0.131	-0.005	0.134	-0.074	0.014	0.088	0.065	0.062	0.007	0.087	-0.111	0.445	1.000	
16	Low-tech sector	0.057	-0.023	-0.014	-0.016	-0.046	0.014	-0.018	-0.010	-0.041	-0.016	-0.005	-0.104	-0.032	-0.043	0.017	1.000

Table A1 (Cont.)
Correlation Matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
17	High-tech Sector	-0.024	0.034	-0.023	-0.011	0.014	0.008	0.050	0.025	0.082	0.067	-0.006	0.033	0.028	0.014	-0.047	-0.332
18	Industrial level for financing sources	-0.081	0.020	-0.013	0.019	0.076	-0.033	0.041	0.038	0.048	0.051	-0.022	0.039	0.068	0.037	-0.006	-0.306
19	Industrial level for market scope	-0.029	0.018	0.007	-0.005	0.021	0.000	0.035	0.015	0.065	0.043	-0.024	0.080	0.031	0.014	-0.008	-0.404

		17	18	19
17	High-tech Sector	1.000		
18	Industrial level for financing sources	0.232	1.000	
19	Industrial level for market scope	0.354	0.276	1.000

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Castany, L (AQR-IREA)**; López-Bazo, E.** (AQR-IREA)**.**;**Moreno** , **R.** (AQR-IREA)
"Decomposing differences in total factor productivity across firm size"
(Març 2007)

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Raymond, J. Ll. (GEAP)**; Roig, J. Ll.** (GEAP)
"Una propuesta de evaluación de las externalidades de capital humano en la empresa"
(Abril 2007)

XREAP2007-03
Durán, J. M. (IEB)**; Esteller, A.** (IEB)
"An empirical analysis of wealth taxation: Equity vs. Tax compliance"
(Juny 2007)

XREAP2007-04
Matas, A. (GEAP)**; Raymond, J.Ll.** (GEAP)
"Cross-section data, disequilibrium situations and estimated coefficients: evidence from car ownership demand"
(Juny 2007)

XREAP2007-05
Jofre-Montseny, J. (IEB)**; Solé-Ollé, A.** (IEB)
"Tax differentials and agglomeration economies in intraregional firm location"
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Albalate, D. (PPRE-IREA)
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Segarra-Blasco, A. (GRIT);
"Innovation, R&D spillovers and productivity: the role of knowledge-intensive services"
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Bermúdez Morata, Ll. (RFA-IREA); **Guillén Estany, M.** (RFA-IREA), **Solé Auró, A**. (RFA-IREA)
"Impacto de la inmigración sobre la esperanza de vida en salud y en discapacidad de la población española"
(Novembre 2007)

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XREAP2007-15
Sánchez Hugalbe, A. (IEB)
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