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ENHANCING INNOVATION PERFORMANCE THROUGH EXPLOITING COMPLEMENTARITY IN SEARCH BREADTH AND DEPTH

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ENHANCING INNOVATION PERFORMANCE THROUGH EXPLOITING COMPLEMENTARITY IN SEARCH BREADTH AND DEPTH

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ABSTRACT

Innovation speed is central to competitive advantage. Since innovation is a complex process of bundling technologies and solving problems, enhancing innovation speed could require ambidextrous search strategies. Empirical work on innovation search has identified both tradeoffs and synergies between search-breadth and search-depth on the number of innovations firms introduce, the radicalness of innovations, or on firm-performance at large. The innovation-speed literature has focused on “development factors” enabling firms to accelerate their innovative efforts. Both literatures, however, have not been connected to date and we do not know if breadth and depth allows firms to problem-solve more effectively, thus improving innovation speed. The study suggests that explorative and exploitative search can lead to more efficient problem-solving and speed up the innovation process, providing competitive advantages quite distinct from affecting the rate and magnitude of innovation.

INTRODUCTION

Innovation speed is a central factor to competitive advantage, and especially so in high-velocity environments (Eisenhardt & Tabrizi, 1995). More specifically, faster development of innovations forms an important potential source of first-mover advantages (Lieberman & Montgomery, 1988). Speedy market introduction of innovations allows sooner recovery of development costs from early revenues, helps creating product legitimacy, helps building early market-share (Schoonhoven, Eisenhardt, & Lyman, 1990), and generates early information and dynamic learning about the preferences of new markets ahead of rivals. As a result, pioneers and early-movers have been found to enjoy both a lasting pricing advantage, and a more sustainable market share advantage (Makadok, 1998).

Furthermore, technological opportunities tend to wane by the lapse of time, and so any firm that observes and seeks to exploit an opportunity needs to act swiftly before it gets noticed by rivals, or before the opportunity gets barred by the emergence of subsequent opportunities (Katila & Mang, 2003). It is therefore unsurprising that faster development times have been found to positively affect new product success (Jiyao Chen, Reilly, & Lynn, 2005; Johnson, Piccolotto, & Filippini, 2009).

Thus far, the empirical search literature has been concerned with more “downstream” performance outcomes of search patterns. One group of work focuses on the rate, or number of new products that firms introduce, or innovativeness (Katila & Ahuja, 2002; Keld Laursen, 2006; Rothaermel & Alexandre, 2009; Sidhu, Commandeur, & Volberda, 2007; Wu & Shanley, 2009). Other work has examined the impact of search patterns on the magnitude (e.g. incremental vs. radical) of innovations that firms are able to introduce (Ahuja & Lampert, 2001; Rosenkopf & Nerkar, 2001). A third group of studies examines the effects of search behavior on firm-
performance as the most downstream performance outcome of search strategies (Auh & Menguc, 2005; Cao, Gedajlovic, & Zhang, 2009; He & Wong, 2004; Rothaermel & Alexandre, 2009).

Thus, while the literature on innovation-search has been generally concerned with firm-level outcomes and has established important findings, far less is yet understood about how search behaviors can lead to these more final outcomes of search activities. From both the innovation-speed and -search literatures, it remains therefore unclear whether the bundling of technologies and associated problem-solving processes in new product development can gain efficiency from search strategies. Our work suggests that explorative and exploitative search patterns may yield more immediate returns than previously assumed by studies that have looked at the rate and magnitude of innovation, as well as firm-performance more generally. We uncover this unexplored issue by connecting to the New Product Development (NPD) literature, and study the relationship between search patterns and the achieved speed of innovation, on the new product development project-level, as a key process-performance outcome that is known to have lasting firm-level performance effects. Exploring the intersection of innovation-speed and -search is also a natural step, because both literatures view innovation as a key means of organizational adaptation and sustaining competitive advantage (Brown & Eisenhardt, 1995; Katila & Ahuja, 2002; Kessler & Chakrabarti, 1996). In addition, the speed of organizational action has not only been viewed as an organizational competence and advocated in product development studies (Eisenhardt & Tabrizi, 1995), but also in other contexts such as competitive action (Ferrier, Smith, & Grimm, 1999) and new venture growth (Baum & Bird, 2009). Thus, the temporal dimension of innovation and organizational action is an important area and of consistent interest to organization scholars seeking to understand the effects of adaptation processes and sources of competitive advantage.

**THEORY AND HYPOTHESES**

**Explorative and Exploitative Search in Innovation**

Since the seminal paper by March (1991), exploration and exploitation have become major constructs in describing the nature of organizational learning and adaptation. Consequently, the literature on organizational change through adaptive search for new technologies has characterized fundamentally differing search strategies frequently in terms of being “explorative” or “exploitative”. Since innovation is a strategic activity, innovative search by a firm can for example be triggered because a rival firm has introduced a significant innovation to the market (Greve & Taylor, 2000; Henderson & Clark, 1990), if profits are falling below what is desired or necessary to survive, or if an entrepreneurial opportunity is recognized (Ahuja & Lampert, 2001). Researchers have conceptualized this process of firms looking for alternative solutions as the probing of a “search space” of potential alternatives, in which search can stretch from extreme exploitation to extreme exploration. In spite of the central role these two notions of organizational learning play in this literature, their interpretation has been somewhat fragmented, and it is useful to first pay brief attention to this.

On the one hand, some researchers have explained the role of exploitation as enhancing the appropriation of returns on firms’ search for new innovations. In this view, in order to survive, a firm has to not only search for new product innovations in the face of technological change, but also seek to subsequently “exploit” the returns of the costly exploration-efforts associated with innovating. This can be achieved by developing complementary processes that enable a firm to efficiently capture the value of their innovation (Teece, 1986). Here, exploitation is a form of learning associated with building economies of scale and scope around recently introduced
innovations. The other view of exploitation treats the construct as a different type of learning that arises from a firm specializing in a particular domain or technology. This form of exploitation is seen as allowing firms to build up a more solid, deeper understanding of the knowledge and resources a firm already possesses.

Clearly, these two views of exploitation will have distinct causal relationships to firm performance. Staying in line with prior work that has examined the role of knowledge-search in innovation performance (e.g. Katila & Ahuja, 2002; Keld Laursen, 2006), our study focuses on the complementary roles of exploration and exploitation have for innovation. Therefore, we adhere to ‘exploitation’ as being the learning from specialization in a knowledge domain or technology. In this view, exploitation-type learning is characterized by a degree of connectedness, although not in the structural sense (e.g. Sheremata, 2000), but in the sense of the cumulative development of knowledge within a known, or proximate technological boundary, often aimed at making improvements over time. Thus in our theorizing, exploitation refers to learning by refinement and extension and the building and using of a critical mass of knowledge in a domain (Gupta, Smith, & Shalley, 2006; March, 1991).

We perceive exploration, on the other hand, as a form of learning that crosses technological boundaries and the searching of new, more distant knowledge-domains, that bring in novel variation to a firm (Baum, Li, & Usher, 2000; Benner & Tushman, 2002; He & Wong, 2004). Furthermore, because the knowledge that has been historically built up inside organizations is idiosyncratic (Grant, 1996), and resides significantly in a firm’s own social communities (Zander & Kogut, 1995), exploration can also occur by searching beyond organizational boundaries (Cassiman & Veugelers, 2006; Raisch, Birkinshaw, Probst, & Tushman, 2009; e.g. Rosenkopf & Nerkar, 2001; Rothaermel & Alexandre, 2009).

Accordingly for our purposes, exploration refers in general terms to innovative search that creates distal experience, whereas exploitation refers search for innovation that creates proximal experience. Because the notions “proximal” and “distal” are relative to the different dimensions of search described above, we unpack exploration and exploitation into more specific constructs that have been used in prior work.

First, the aspect of refinement inherent in exploitation implies that exploitative search entails a degree of use and reuse of existing knowledge as a matter of concentration in a given knowledge area. This idea of applying extant knowledge for innovative use by firms can also be found in work that portrays innovative search as recombinant (e.g. Fleming, 2001; Henderson & Clark, 1990) and innovations as the outcome of novel combinations (Schumpeter, 1934). This dimension of search thus refers to the degree to which a firm concentrates the use of knowledge within a single domain and labels this search depth.

On the contrary, a firm may engage in exploration by choosing how widely it searches for new knowledge. To realize this, a firm may choose to engage into accessing the domains of different types of organizations as external sources of new knowledge. In line with Laursen and Salter (2006), we term the latter search breadth.

**Breadth and Scope of Search**

There are some indications in the New Product Development literature that exploration-type search may be a relevant determinant of innovation speed. For example, approaches which view the product development process as a practice of communication have highlighted the importance
of increasing the amount and variety of information as improving the performance of the development-process (Brown & Eisenhardt, 1995). Other work on innovation speed has found that the speed of development depends in part on whether the technologies and knowledge are developed in-house or acquired externally (Eric H. Kessler, Paul E. Bierly, Shanthi Gopalakrishnan, 2000; Gold, 1987; Kessler & Chakrabarti, 1996; McDonough & Barczak, 1991).

Because innovation entails the creation and development of new ideas, and brings about varying degrees of knowledge synthesis and recombination, there is a considerable degree of both technical and market uncertainty encountered when the idea is gradually transformed into a marketable offering. In order to deal effectively with the issues and errors that arise during the development of an innovation, firms need to create or access, and store rich sets of knowledge elements that bring a requisite degree of variety upon which they can draw in confronting encountered problems (Ven, 1986). Such variety of knowledge not only facilitates creative potential for improvisation and flexibility when problems are encountered, but potentially also helps to detect problems sooner. To the extent that encountered problems are unforeseen at the time development starts, a richer amount of available information increases the likelihood that problems are spotted earlier on in the development process, preventing more time-consuming problem-solving during later stages in which changes are often harder to make. One other issue distinct from problem-solving is that a broader set of knowledge elements also allows firms to go through ‘multiple design iterations’ during the early, prototyping phase of development. This may increase the odds of success to find a well-working design, and thus can help saving valuable time during the early phases of development and provide a more solid basis of the innovation process (Eisenhardt & Tabrizi, 1995).

While accessing and creating richer sets of knowledge elements may have clear benefits for potentially speeding up innovation processes, its positive effects are not likely limitless and experimentation with new knowledge may also decrease innovation speed. First, the integration of different and unfamiliar knowledge areas can be problematic, and has highly uncertain outcomes (Fleming, 2001). Second, accessing varied and creating rich knowledge sets means that product-development teams are confronted with more diverse information as well. Excess contact with broader and less familiar sets of knowledge ultimately impedes the execution of development work generally, because there is less aptitude for teamwork (Ancona & Caldwell, 1992; Carbonell & Rodriguez, 2006). Second, if a firm engages in too much exploration, it will be more difficult to establish appropriate problem-solving routines not only because the firm is less familiar with the new knowledge, but also because the set of potential problem-areas expands. Furthermore, to the extent that explorative search exceeds organizational boundaries, externally searched knowledge usually takes longer to integrate with the firm’s internal knowledge base across organizational boundaries, and the degree by which this can occur is conditional on the stock of prior internal knowledge of the firm (Cassiman & Veugelers, 2006; Cohen & Levinthal, 1990). Thus, while broader search can enhance innovation speed by increasing the amount and diversity of available knowledge for problem-solving and trying different design variations, integrating and applying different and unfamiliar knowledge areas comes at the cost of slower innovation speed.

*Hypothesis 1: There is an inverted U-shaped relationship between the breadth/scope of search and innovation speed.*

**Depth of Search**

As pointed out above, exploitative search entails a degree of use and reuse of existing knowledge, or knowledge that is proximal to the firm’s extant knowledge. This kind of focused
development of knowledge may have several benefits for the realization of new product development projects. First, it is likely that prior experience in a technological area reduces uncertainty inherent in the development of a specific technology for an innovation within that area. Engineers, for example, may be better able to predict the consequences of changing configurations and parameters.

Second, knowing a technological domain well also implies that the search for solutions outside the immediate firm-level knowledge elements but within the domain can be done more efficiently. The prior experience will allow R&D workers and managers to not only know where to look for solutions outside the organization, but also to make faster and more accurate assessments of their potential value.

Third, previous research has found that internal communication improves development-team performance (Brown & Eisenhardt, 1995). To the extent that focus and experience in a technological domain will structure also communication and thus the internal information flow, exploitative, “deep” search will facilitate more comprehensive information and thus improves development-process performance.

However, rarely are innovations that simple that they will span only a single knowledge domain. Applying extant knowledge for innovative use requires innovative search to be at least recombinant (e.g. Fleming, 2001; Henderson & Clark, 1990). Because of the larger levels of interaction associated with recombining knowledge innovatively, greater than moderate levels of search depth will ultimately offset its benefits, and make speedy problem-solving more difficult. An over-reliance on search depth will make problem-solving more rigid and impede development activity on the boundary between knowledge areas. Thus, we hypothesize:

**Hypothesis 2: There is an inverted U-shaped relationship between the depth of search and innovation speed.**

**Concurrent Breadth and Depth of Search**

A final theoretical question worth of consideration is whether the two types of search are simultaneously achievable by any one firm (Katila & Ahuja, 2002; Raisch & Birkinshaw, 2008), or whether they are fundamentally incompatible and thus impose a trade-off situation for a firm (Atul Nerkar, 2004; March, 1991). Ultimately this is an epistemological question, but because we perceive exploration to occur also by organizational boundary-spanning search, and because recent studies have found evidence of simultaneous, synergistic achievement of explorative and exploitative search in the context of innovation (He & Wong, 2004; Katila & Ahuja, 2002), we consider the theoretical possibility that firms’ search can be concurrently exploitative and explorative.

In deriving the two hypotheses above, it also becomes apparent that broad and deep search generates distinct advantages for speeding up the development process.

One the one hand, search breadth facilitates creative potential for improvisation and flexibility when problems are encountered, and potentially also helps to detect problems sooner. On the other hand, too much search depth alone may reduce the likelihood of problems occurring with the search domain, but will also create blind-spots of unforeseen problems, with hard-to find solutions outside the scope of the knowledge domain. We therefore expect that concurrent broad and deep
search will have a joint effect and shorten the duration of a firm’s innovation process. Thus, we hypothesize:

**Hypothesis 3:** Because combined breadth and depth of search allow for more efficient problem-solving, there will be a positive interaction-effect of search breadth and depth on innovation speed.

**DATA AND METHODS**

Our primary data source is the SFINNO database of Finnish innovations. This unique database combined innovation counting from announcements in technical and trade journals, technological expert opinion (e.g. Coombs, Narandren, & Richards, 1996; Katila & Ahuja, 2002; Kleinknecht & Bain, 1993) complemented by systematic reviewing of annual reports. The latter method was applied because prior research has found that literature-based innovation-counting might underestimate innovations from large firms (Acs & Audretsch, 1993). Complementary data on the commercializing firms has been collected from secondary sources, such as the business register maintained by Statistics Finland. A questionnaire—where it was possible to identify a knowledgeable respondent who had followed the various development phases of the innovation or else directed to the firm’s R&D manager—was used to collect more detailed information related to the innovation and the innovation process. The questionnaire’s cover note described the innovation in question as precisely as possible to clarify the object of the questionnaire. On the side of the researchers collecting the innovation counts, innovation has been defined as an “invention that has been commercialized on the market by a business firm or the equivalent”, following the OECD Oslo Manual’s definition of innovation (OECD, 2005).

We analyze 735 innovations reported in the public domain in Finland between 1990-2007 from the SFINNO database. From the aforementioned questionnaire, we use self-reported stakeholder involvement in discrete innovation processes to operationalize breadth and depth of search. This survey also provides new product development-timelines. A polynomial regression approach was used to assess the hypothesized inverted u-shaped relationships.

**Measures**

Our dependent variable is Innovation Speed \( (Speed) \), and is defined as the time elapsed between the first conception and definition of an innovation and its introduction in the market (Kessler & Chakrabarti, 1996; Mansfield, 1988). Thus, we measure speed on the project-level, as recommended by Kessler and Chakrabarti (1996). We calculated Innovation Speed as the difference between the year in which the idea was conceived, and the year in which the innovation was launched on the market plus one. The value of one was added to the commercialization year in order to avoid zero values for projects completed within one year. We then multiplied this time-difference by -1 so as to get a measure of speediness.

As an independent variable, we constructed **Breadth** as a combination of the knowledge domains that the focal-firm tapped into for the innovation process that generated the new product. The domains consist of the various types of organizations the innovating firm indicated to have had significant collaboration with during the innovation process. These are made up of: customers, consultants, subcontractors, competitors, universities and research centers (both domestic and foreign). Each possible type of organization was first dummy-coded with 1 denoting collaboration, and subsequently we added up their values for each discrete innovation process. The underlying
principle is that firms that collaborated with more types of organizations display a broader knowledge domain search strategy.

Similarly, we constructed *Depth* counting the same domains of search, but instead of dummies we used a four-point Likert scale indicating the degree of intensity of each domain, varying from not important to great importance. This provided a measure of depth of the collaborations. Both Depth and Breadth of search have been constructed in similar ways in prior research (Keld Laursen, 2006; Leiponen & Helfat, 2010).

**Control Variables**

Firstly, we include 23 industry controls to account for industry-specific new product development time-lines (see Table 2). Second, we include the number of establishments of firms, because the presence in multiple locations may affect information flows, for example from localized spillovers (Aharonson, Baum, & Feldman, 2007; e.g. Zucker, Darby, & Armstrong, 1998), which in turn can determine new product development speed. Third, we include a dummy \((R_D)\), indicating whether the firm used its own R&D facilities in developing the innovation. This is a self-reported item from the SFINNO survey data. Lastly, we include two measures of firm-size, personnel size \((\text{Size}_{\text{pers}})\), and turnover size \((\text{Size}_{\text{turn}})\) since size can be an important determinant of organizational processes.

**RESULTS AND DISCUSSION**

The regression results can be found in Table 1. Our first hypothesis proposed that broader search can enhance innovation speed by increasing the amount and diversity of available knowledge for problem-solving and trying different design variations, while integrating and applying different and unfamiliar knowledge areas comes at the cost of slower innovation speed. Table 1 provides strong support for the hypothesized inverted u-shaped relationship between innovation speed and search breadth. The parameter for *Breadth* is both positive and significant. As expected, the parameter for *Breadth\_Square* is both negative and significant, suggesting the curvilinear relationship between breadth and speed indeed exists.

Hypothesis two proposed that search depth will enhance communication and problem solving, and thus improve innovation speed, while greater than moderate levels of search depth will ultimately offset its benefits, and make speedy problem-solving more rigid and slow down new product development. Table 1 provides support also for the hypothesized inverted u-shaped relationship between innovation speed and search depth. The parameter for *Depth* is both positive and significant. As expected, the parameter for *Depth\_Square* is both negative and highly significant; suggesting also a curvilinear relationship between depth and speed indeed exists.

Finally, we look at complementarity between search breadth and depth in enhancing innovation speed. Our third hypothesis suggested that simultaneously combined breadth and depth of search should allow for more efficient problem-solving as they provide different, complementary advantages. The regression results in Table 1 indeed show a positive and significant interaction-effect of search breadth and -depth on innovation speed. Thus, we find empirical support for the idea that seeking breadth and depth simultaneously may improve innovation-process performance by facilitating more efficient problem-solving.

**CONCLUSIONS**
This study has examined the effects of search strategies on the speed of innovation, i.e. how quickly an idea for an innovation is brought to the market place. The project-level of analysis of performance outcomes has been common in New Product Development studies, but not in the literature on search for innovation. We found an curvilinear, inverted u-shaped relationship between both search breadth and innovation speed, as well as for the relationship between search depth and innovation speed. In addition, we found support for the idea that combining breadth and depth has a positive effect on innovation speed, because both strategies offer distinct efficiency advantages to the problem-solving inherent in innovating.

A limitation of the present study is that despite taking up industry controls, we have not examined the potential effect of environmental conditions on innovation speed. It is likely that environmental complexity and levels of competition will be important determinants of innovation speed. Therefore, future work should take the ways these factors influence innovation speed into account in order to get a more refined understanding of the role of various search strategies under different circumstances. It may be that search strategies have different effects under different environmental circumstances, and this would be an interesting avenue for further work. Also a limitation of this study, how radical and technologically complex new products are can be expected to affect innovation speed. Thus, future work should take these innovation-level characteristics into account.

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REFERENCES


### Table 1: Moderated Polynomial Regression Results, Explaining Innovation Speed

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Std. Error</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breadth</td>
<td>.537***</td>
<td>.202</td>
</tr>
<tr>
<td>Depth</td>
<td>.146**</td>
<td>.048</td>
</tr>
<tr>
<td>Breadth_Square</td>
<td>-.641***</td>
<td>.024</td>
</tr>
<tr>
<td>Depth_Square</td>
<td>-.736***</td>
<td>.001</td>
</tr>
<tr>
<td>BreadthXDepth</td>
<td>.081**</td>
<td>.034</td>
</tr>
<tr>
<td>R_D</td>
<td>.074</td>
<td>.549</td>
</tr>
<tr>
<td>No of establishments</td>
<td>.009</td>
<td>.001</td>
</tr>
<tr>
<td>Size_pers</td>
<td>-.045**</td>
<td>.000</td>
</tr>
<tr>
<td>Size_turn</td>
<td>.016</td>
<td>.000</td>
</tr>
<tr>
<td>Industry Dummies</td>
<td>yes</td>
<td></td>
</tr>
</tbody>
</table>

* = p < 0.10  ** = p < 0.05  *** = p < 0.01

### Table 2: Industry Controls

- Agriculture, forestry and fisheries
- Mining of minerals
- Food, beverages and tobacco
- Textiles, apparel, leather, footwear
- Wood and wood products
- Pulp and paper
- Publishing and printing
- Chemicals, rubber, plastics, oil
- Glass, ceramic products, concrete
- Basic metals, metal products
- Machinery and equipment
- Electro-technical products
- Transport equipment
- Other industry, recycling
- Electricity, gas and water supply
- Construction
- Trade, hotels, restaurants, etc.
- Transport
- Telecommunications
- Financial and insurance services
- Data processing services
- Technical services
- Other services