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Younes Iferd
Patrick Plötz

External search strategies: The role of innovation objectives and specialization

Fraunhofer
ISI

Abstract

Firms are increasingly competing in an open innovation environment. Search strategies for external knowledge therefore become decisive for firms' success. Existing research distinguishes between breadth (diversity) and depth (intensity) with which firms deal with external knowledge sources. However, relatively little is known about how mangers can selectively strengthen one of these dimensions. We argue conceptually that the effect of breadth and depth of a research strategy on the innovation performance depends on (1) the type of innovation objectives (explorative vs. exploitative innovation objectives) and (2) the nature of the firm's orientation in drawing on external knowledge (science-based or market-based orientation). We test these hypotheses empirically for a sample of 1,434 manufacturing firms in Germany. Our results show that explorative innovation objectives strengthen the effect of breadth on innovation performance while exploitive objectives increase the depth. Moreover, we find that market-driven strategy favours breadth while science-driven strategy is more prevalent for depth search strategy.

Keywords: open innovation, exploitative/explorative search strategies, market/science-driven strategies

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1 Introduction

Competitive advantages have often been shown to be the results of a firm's successful innovation activities (Banbury and Mitchell 1995; Brockhoff 1999). In this context, it has almost become conventional that in-house research and development is often not the only way to create new technological knowledge and bring innovation to market. Since the sources of new technologies are very varied, it is highly probable that at least from time to time firms need to acquire knowledge externally (Teece 1986, 1992). In fact, many firms have begun to open their innovation processes to external knowledge. This trend of so-called "open innovation" allows firms to access and exploit external knowledge while internal resources are focused on core activities (Chesbrough 2003). External sources for innovation impulses like competitors, customers or universities can be considered the main elements of the a firm's search strategy, which has been shown to have a significant positive impact on innovation performance (Katila and Ahuja 2002; Laursen and Salter 2006).

Research on the nature of these strategies has mainly focused on the dimensions of breadth and depth (Katila and Ahuja 2002; Laursen and Salter 2006). The breadth refers to the diversity of types of external knowledge, while the depth reflects the intensity of external search activities.

A firm’s search behaviour is shaped by prior experiences and current needs. According to Laursen and Salter (2006: 134), “it is difficult for many organizations to determine the ‘optimal’ search strategy in terms of ‘broader and deeper’, especially in situations where there is turbulence in the knowledge base of the firm.” Thus, a firm’s optimal search strategy is driven by internal knowledge requirements and environmental context.

Managers therefore need to think about ways to optimize their firm's external search strategies. However, relatively little is known on how managers can strategically and profitably use individual dimensions of their external search strategy (breadth and depth). Meaning, how to improve breadth instead of depth and vice versa. This leaves a question unanswered: Why are some firms more inclined toward breadth while other firms tend to rely on depth?

In this study, we contribute to literature concerning the impact of firm's openness on their innovation performance by extending the analysis of external search strategies of Laursen and Salter (2006). Accordingly, we argue that the effectiveness of the search strategy for increasing innovation performance should depend upon two critical moderating factors: innovation objectives (explorative vs. exploitative innovation objective) as well as science-based or market-based orientation of the firms, when drawing external knowledge.

Using the German Community Innovation Survey (CIS) data from 2009 we employ a Tobit regression model, showing that both moderating effects have a crucial role to play: On the one hand, external research breadth is most effective when the firms pursue more explorative innovation objectives, while depth is more effective when the firms have more exploitative innovation objectives. On the other hand, breadth is more beneficial when the firms obtain external knowledge from the market (market-based orientation), while depth is more effective when the firms are more science-based oriented.

The remainder of the paper is organised as follows: The next section provides a review of the relevant literature and formulates a number of the research hypotheses. The third section describes the data and methodology, followed by the results. Conclusions are discussed in section five.

2 Theory and hypotheses

2.1 Searching for external knowledge sources

Until recently, large firms relied on internal R&D to create new products. In many industries, large internal R&D are perceived as a strategic asset and as constituting a high entry barrier for potential rivals. As a result, large firms with well-developed R&D capabilities could surpass smaller rivals (Teece 1986). This process in which firms develop and commercialise technologies internally has been classified as closed open innovation model (Chesbrough 2003). Although this model worked for some time, the actual innovation landscape has changed. Considering labour mobility and widely dispersed knowledge across various public and private organisations, firms are no longer able to innovate alone, but rather need to engage in alternative innovation practices. As a result of this, many firms have moved to an open innovation model in which they combine both internal and external knowledge in their innovation process (Chesbrough 2003). This process redefines the boundary between the firms and their environment, making the firm more open and involved in networks of various actors. Chesbrough (2006) seems to take the view that firms that are too focused on internal knowledge tend to miss a number of different external opportunities, which can successfully be combined in the firms' internal innovation processes. Research has revealed that increasing integration of external knowledge in firms' innovation processes improve their innovation success (Gemünden, Heydebreck, and Herden 1992; Laursen and Salter 2006; Love and Roper 2004).

A crucial element in open innovation activities of firms is the search for external knowledge. This comprises organisation's problem-solving activities that involve the creation and recombination of technological ideas (Katila and Ahuja 2002). Consequently, investments in problem-solving activities should result in beneficial combinations and linkages of users, suppliers, universities and other relevant actors in the innovation process of firms.

More recent literature has examined various search strategies in order to identify promising external knowledge in a firm's environment (Katila and Ahuja 2002; Laursen and Salter 2006). External search strategies can be conceptualised and classified in different ways. Laursen and Salter (2006) have classified firms' search strategies with regard to their breadth and depth. Search breadth refers to the number of diverse external inputs a firm seeks knowledge from, search depth refers to how intensively a firm draws from each source of external knowledge. Both dimensions (breadth and depth) describe a firm's openness to external knowledge. The relationship between searching widely and deeply and innovation performance is curvilinear (following an inverted U-shape), as found by Laursen and Salter (2006) in their study of the manufacturing industry in the UK. Thus, while search breadth and depth increase the innovation performance, there is a point where additional search efforts become unproductive.

A similar approach is used by Katila and Ahuja (2002). They examined how firms search, or solve problems, to create new products. Their findings in the global robotics industry indicate that firms' search efforts actually vary across two distinct dimensions: search depth and scope. Contrary to Laursen and Salter (2006), they define search depth as the extent to which a firm reuses existing internal knowledge, while search scope indicates how widely a firm explores externally available knowledge. The latter largely corresponds to search breadth as defined by Laursen and Salter (2006). In accordance with the conclusions of Laursen and Salter (2006), Katila and Ahuja (2002) found an inverted U-shaped relationship between the search effort and innovation performance, which again shows a negative effect of search activities being too extensive.

A firm's optimal search strategy is driven by both internal knowledge requirements and environmental context (Laursen and Salter 2006). Hence, management decisions are necessary for the firms to optimise their external search strategies. However, relatively little is known on how managers can strategically and profitably use individual dimensions of their search strategy. Meaning how to improve breadth instead of depth and vice versa. Our aim is to expand this field of research by untangling the process behind adopting external breadth and depth strategies. We argue that this depends on which innovation objectives (explorative vs. exploitative innovation objective) the firms pursue and on whether the firms are science-based or market-based when drawing on external knowledge.

2.2 Explorative and exploitative innovation objective

We propose to test our hypotheses (formulated in section two) about breadth and depth of external knowledge in the particular context of technological innovation. Following the OCED (2005) in the *Oslo Manual* we distinguish two types of innovations: technological innovation (product and process innovation) and non-technological innovation (marketing and organisational innovation). This paper focuses on how firms commercialise new technological knowledge and ideas in the form of new products, as opposed to non-technological innovation, which involves changes to organisational structures or administrative processes.

While various typologies of technological innovation strategies have been used in the innovation management literature, very little has been clearly and explicitly based on the exploration and exploitation constructs. Zahra and Das (1993) presented the four most used types of innovation strategy: 1. pioneer versus follower; 2. product versus process innovation; 3. the intensity of investment in innovation (low versus middle versus high); and 4. internal versus external innovation, but none of them is based directly on exploration and exploitation. Henderson (1999) divided the innovation strategies into two constructs: proprietary versus standards-based strategies. The first may be more closely linked to technological exploration while the second may be more closely linked to exploitation.

In this paper, we adopt the starting point of Henderson (1999) and we define an *explorative innovation objective* for the labelling of innovation activities aiming to enter new product-market domains and an *exploitative innovation objective* to denote technological activities, the objective of which is to improve an existing product-market position.

Firms with particular emphasis on explorative innovation strategy intend to search for new, technology-based business opportunities that are relatively new to the company and the outcome of which cannot be predicted at the start, however, this is an entrepreneurial search process for business opportunities in technological areas. Therefore, companies try to gain a first, quick understanding of many different alternatives of external knowledge sources. External information is broad and general in nature, because the focus lies on identifying alternatives rather than improving existing products perfectly. This task does not have a well-defined solution space, thus firms perform broad searches of their environments in order to identify a variety of future options (Rowley, Behrens, and Krackhardt 2000a). Since firms want to cover a relatively broad range of external information sources of innovation, it can be argued that a broad variety of sources may be important, because by employing several external sources at the same time, firms hedge the risks associated with missing out on a relevant new source (Nicholls-Nixon and Woo 2003).

Hypothesis 1: External search breadth will be *most important where firms' innovation objective is more explorative.*

In contrast, we argue that external search depth offers considerable advantages when a company is primarily interested in the refinement of existing products. Exploitative innovation objectives imply that firms refine and strengthen their existing products base and for that they need specific and detailed external information which provides a deeper understanding knowledge of this particular technology. In contrast to explorative innovation objectives, exploitative objectives require a deeper understanding of specific information rather than a wider grasp of general information (Rowley, Behrens, and Krackhardt 2000b). This deepens the understanding of concepts and scientific principles underlying the improvement of product innovation and reduces potential errors, leading to more reliable and predictable outcomes. Accordingly, we expect the use of a new external source of innovation -used intensively- to be important in the case of exploitative innovation objectives:

Hypothesis 2: External search depth will be most important where firms' innovation objective is more exploitative.

2.3 Science-driven and market-driven search strategy

Science-driven search requires a different set of specialised competencies. Universities are the primary producers of sound new knowledge and technologies. The knowledge produced often shows a high degree of novelty, which offers important and lucrative business opportunities (Cohen, Nelson, and Walsh 2002). In addition, academic incentive systems aiming at publication and dissemination make scientific knowledge a public good to a large extent (Perkmann and Walsh 2007). However, knowledge generated at a university is often further removed from commercial applications and requires significant investment in development to commercialise it (Link et al., 2007; Siegel et al., 2004). In addition, companies need special absorption capacities to assess and communicate this type of knowledge. The decisive factor is that the full value of the often tacit and causally unclear knowledge can only be assessed through joint and extensive research activities in which university and company scientists over time develop a mutual understanding and a common language in practice (Laursen and Salter 2006). This means that the science-driven search for knowledge requires firms to maintain intensive, permanent and deep contact with science. In this context, activities such as discussing ideas, exchanging views, the reformulation of strategies when unforeseen problems emerge and common trial and error procedures are of greater importance. Accordingly, we expect that firms, which are science-driven will rely on the depth search strategy.

Hypothesis 3: The science-driven orientation of the firm is complementary to the external search depth in shaping innovative performance.

The product market side has attracted particular attention in marketing literature in the context of the market orientation of companies. (Kohli and Jaworski 1990). This broader conceptualisation underlines the change in corporate culture towards creating added value for customers (Slater and Narver 2000). Customers, competitors and suppliers can be considered the central elements of a product market-driven external knowledge search. Impulses from these groups have been found to contribute to innovation success. Customers are a valuable source for innovation when their specific demands are anticipatory for larger market segments in the future. However, identifying and finding these lead users may be difficult. Frosch (1996) points out that incorporating customer impulses into an innovation process is generally risky. Their impulses can be myopic, narrow and often wrong. Their knowledge is frequently unarticulated (Zedtwitz and Gassmann 2002). This makes the transfer and separation of knowledge from its original context difficult. In other words, the knowledge of users remains "sticky" (Szulanski 1996). The literature has therefore cautioned managers not to focus deeply on the immediate needs of customers. Competitor knowledge is different in relation to its accessibility. Competitors operate in a similar market and technologies context (Dussauge, Garrette, and Mitchell 2000). Their knowledge is often incorporated in the products and services available on the market. That makes it easier to identify important aspects and absorb them. Therefore, it is maybe not absolutely necessary to deal intensively with the knowledge of competitors. Suppliers have been identified as an relevant driver for innovation success (Pavitt 1984). However, Kotabe (1990) found that firms that heavily use suppliers knowledge may lose important manufacturing process knowledge. To sum up:, knowledge of customers, competitors and suppliers are all important external sources for the innovation process of market-driven firms, but they should not be used intensively, rather a wide range of these knowledge sources is of greater importance for these firms. Thus we expect that the companies that are market-oriented in obtaining external knowledge tend to focus on the external broad search strategy.

Hypothesis 4: The market-driven orientation of the firm is complementary to the external search breadth in shaping innovative performance.

3 Data and methodology

The data used to test the hypotheses is taken from the Mannheim Innovation Panel (MIP). The MIP is an annual survey of innovation activities of German enterprises. It represents the German contribution to the Community Innovation Surveys (CIS) of the European Commission. It fully complies with the methodological standards laid down for the CIS. The MIP is based on a stratified random sample of enterprises located in Germany with 5 or more employees that have their main economic activity in mining, manufacturing, energy and water supply, sewerage and remediation, wholesale trade, transportation and storage, information and communication services, financial and insurance activities, and other business-oriented services. More details on the MIP can be found in Peters and Rammer (2013)

We use data from the MIP survey conducted in 2009, which collected information on innovation activities of firms conducted during the years 2006 and 2008 and which was the German contribution to the CIS 2008. The MIP survey provides information on the core variables (innovation sales, innovation sources and innovation objectives) described in our theory as well as general information about firms. The MIP data provides information on the two-digit industry code (NACE) of a firm. We restrict our analysis to manufacturing firms in Germany. Table 1 provides details on the industries represented in our empirical analysis.

Table 1: Distribution of the firms in the sample across industries

Manufacturing	NACE Rev. 2	Number of firms	Percentages
Food	10-12	140	10%
Textile	13-15	75	5%
Wood	16	29	2%
Paper	17	39	3%
Printing	18	51	4%
Oil, Chemical	19-21	128	9%
Plastic, Rubber	22	87	6%
Non-Metallic minerals	23	62	4%
Primary metal	24	58	4%
Metal products	25	137	10%
Electronics	26	282	20%
Machines and equipment	27-28	220	15%
Cars, vehicle	29-30	89	6%
Furniture	31	37	3%
Total		1434	100%

The questionnaire of the survey asks general managers, heads of R&D departments or innovation management directly about which source(s) of knowledge they rely upon in their innovation activities and which objectives they pursue in their innovation process. We have chosen the 2009 wave of the MIP data because it contains information about both the sources of information and objectives of innovation.

3.1 Data

3.1.1 Dependent variable

Several authors introduced various concepts for measuring innovation success (Hagedoorn and Cloodt 2003). One possibility is to use innovation inputs (R&D expenditures) as an indicator for innovation effort and indirectly innovation success. Another alternative is to look at the outcome of innovation efforts, such as patents, new products and/or services. The latter is the perspective that we chose for our study.

The success of an innovation largely depends on market acceptance (Mairesse and Mohnen 2002). For this reason, we define innovation success as the sales from new or improved products and use this as dependent variable. The main advantage of this measure is that it captures innovation directly by measuring the introduction and the success of the newly developed products. Conventional innovation measures success such as patents or citation-weighted patents cannot capture the performance of all innovative activity because many innovations are not patented and conversely patented ideas are not commercialised (Kamien and Schwartz 1982; Geroski 1990).

3.1.2 Independent variables

3.1.2.1 Capturing external breadth and depth search strategies

We rely on the survey question to identify the sources of external knowledge and receive importance-weighted answers on the value of their contribution. More precisely, respondents are asked to evaluate the importance of the main sources of their innovation activities on a 4-point Likert scale ranging from 0 "not used" to 3 "high". Table 2 lists all external sources used in this study.

Table 2: External sources and knowledge for innovation activities in German manufacturing

External sources for innovation	Percentages			
	Not used	Low	Medium	High
Customer	36%	12%	24%	29%
Supplier	33%	11%	22%	34%
Competitor	32%	8%	25%	35%
Consulting company	31%	6%	23%	40%
University	35%	14%	26%	25%
Research institute	37%	19%	24%	20%
Trade fairs	37%	19%	25%	19%
Journals	37%	18%	24%	21%
Associations and chambers	43%	21%	23%	13%
Patent specifications	44%	20%	22%	15%
Standardization and standards committees	46%	20%	19%	15%

Following (Laursen and Salter 2006), we construct two index variables to measure the breadth and depth of external search. *External search breadth* is defined by the number of external sources of innovation that were used by the firm, while *external search depth* is defined by the number of external sources of innovation which were highly important for the firm.

3.1.2.2 Moderating variables

- *Capturing explorative and exploitative innovation strategies*

Following Bierly and Daly (2001) and (Katila and Ahuja 2002), we consider the exploration as well as exploitation as two distinct dimensions of learning behaviour, rather than as two ends of a unidimensional scale. We use nine Likert-scale items to measure how firms divided attention and resources between innovation activities with explorative versus exploitative objectives in the last 3 years. These items were designed to measure how important it is for a firm to carry out innovation projects to enter new product-market domains or to improve existing product-market efficiency (e.g., introducing a new generation of products versus improving existing product quality; opening new markets versus reducing production costs). Table 3 lists all nine innovation objectives. Each firm was asked to indicate on a 0-1-2-3 scale the degree of use for each innovation objective. We believe that these items capture some essence of the exploration of new possibilities and exploitation of old certainties.

Table 3: Innovation objectives for innovation

Innovation objectives	Percentages			
	Not used	Low	Medium	High
Extend product range	34%	7%	20%	39%
Replacement of outdated products	36%	12%	24%	29%
Open new markets	33%	11%	22%	34%
Increase market share	32%	8%	25%	35%
Improve production quality	31%	6%	23%	40%
Improve production flexibility	35%	14%	26%	25%
Improve production capacity	37%	19%	24%	20%
Reduce personnel costs	37%	19%	25%	19%
Reduce material and energy costs	37%	18%	24%	21%

Principal component analysis (PCA) (Table 4) was used to reduce the nine items to two variables that can be interpreted as explorative innovation strategy and exploitative innovation strategy with acceptable Cronbach alphas (0.79 and 0.77 respectively). We have based the PCA on polychoric correlation, because the items are ordinal scaled.

We will use the two component scores derived as moderating variables to test our first and second hypotheses.

Table 4: Results of principal component analysis for identifying explorative and exploitative innovation strategies: Component loading after varimax rotation

	Exploitative innovation strategy	Explorative innovation strategy
Extend product range	0.363	**0.784**
Replacement of outdated products	0.539	**0.545**
Open new markets	0.372	**0.788**
Increase market share	0.471	**0.757**
Improve production quality	**0.636**	0.630
Improve production flexibility	**0.704**	0.490
Improve production capacity	**0.709**	0.422
Reduce personnel costs	**0.814**	0.349
Reduce material and energy costs	**0.76**	0.396
Cronbach alpha	0.79	0.77

- *Capturing science-driven and market-driven search strategies*

We argue that R&D managers develop targeted types of external knowledge search with a certain direction. This observation stems from the assumption that firms adopt targeted knowledge searches (Sofka and Grimpe 2010). We therefore use a principal component analysis (Table 5) to identify underlying components.

Table 5: Results of principal component analysis for identifying science-driven and market-driven search strategies: Component loading after varimax rotation

	Market-driven search	Science-driven search
Customer	**0.772**	0.299
Supplier	**0.718**	0.296
Competitor	**0.776**	0.288
Consulting company	0.375	0.470
University	0.297	**0.790**
Research institute	0.233	**0.789**
Trade fairs	**0.702**	0.376
Journals	**0.651**	0.464
Associations and chambers	0.511	**0.517**
Patent specifications	0.353	**0.664**

	Market-driven search	Science-driven search
Standardisation and standards committees	0.421	**0.540**
Cronbach alpha	0.80	0.75

We identify two components with eigenvalue greater than one. The retained components reflect our conceptualisation of knowledge search defined along specific search directions. The first component reflects a considerable contribution to the innovation process coming from the market environment of the firms (customers, suppliers, competitors and trade fairs), while the second component is characterised by the scientific contribution to the innovation process (universities, research institutes and patent specifications).

We will use both derived component scores as focus variables to test our third and fourth hypotheses.

3.1.2.3 Control variables

We include several control variables in our model to account for other factors that may influence the estimation results.

The relationship between firm size and innovative performance has been much debated. Economies of scales in R&D, the ability to spread risks over a portfolio of projects and access to great financial resources give large firms an advantage over small firms (Veugelers 1997). Moreover, large firms are better able to acquire the complementary assets necessary to achieve the commercial success of innovative products (Teece 1986). In this paper we capture the firm size by number of employees (expressed in logarithms).

Clearly, the success of innovative activities in firms relies heavily on the level of investments in R&D. These in-house R&D investments have been found to determine a firm's absorptive capacity for identifying and exploiting external knowledge (Cohen and Levinthal 1989; Zahra and George 2002). Hence, we include the R&D expenditures. Furthermore, we control for whether or not firms engaged in R&D collaboration.

Firms that have greater innovative capability also would be expected to have greater innovation success on average. We control for firms' innovative capability by including the percentage of the firms' employees with university qualifications as proxy for the research training of employees.

In addition, we control for the geographic product market. These variable measures whether the largest market of the firm is perceived to be local, national, EU or other countries. It takes the values from 1 to 4, with 1 corresponding to local and 4 to other countries.

The ability to appropriate returns to innovation also varies by manufacturing industry (Cohen and Levinthal 1989), so we include 14 manufacturing dummy variables to correct for fixed manufacturing effects.

3.2 Methodology

As our dataset contains data from innovators and non-innovators, estimating ordinary least squares (OLS) regression including the observations with dependent variable (sales from new or improved products) on innovation output constrained to zero, would yield inconsistent estimates. Limiting estimation to innovating firms would neglect the information from non-innovating firms and even the OLS would be biased. To address these issues, we use a Tobit model (Greene 2000).

The structure equation in the Tobit model is:

$$y_i^* = X_i \beta + e_i$$

where $e_i \sim N(0, \sigma^2)$. y_i^* is a latent variable that is observed for values greater than 0 and censored otherwise. The observed y_i is defined by the following measurement equation:

$$y_i = \begin{cases} y_i^* = X_i \beta + e_i & if\ y_i^* > 0 \\ 0 & if\ y_i^* < 0 \end{cases}$$

This model is estimated using the method of maximum likelihood (for more detail see Greene (2000)).

However, the assumption of normality of residuals in the standard Tobit model is not satisfied in our cases, because the variable reflecting the innovative performance of firms (dependent variable) is highly skewed. Under these conditions, the maximum likelihood estimators of the standard Tobit model are not consistent. Accordingly, we use Box-Cox transformation for censored data presented by Han and Kronmal (2004). The aim is to improve the validity of the Tobit assumptions.

4 Results

Descriptive statistics are given in Table 6. From the table, it can be seen that firms on average have higher external search breadth than depth, firms use about six sources of knowledge for their innovation activities, but they use only one source deeply.

Table 6: Descriptive statistics

	No. of Firms	Mean	S.D	Min	Max
Sales with new products (1000 €)	1434	60.79	746.12	0	26478.22
Breadth	1434	5.70	4.30	0	11
Depth	1434	1.02	1.40	0	10
Science-driven search strategy (factor)	1434	0.16	1.12	-1.81	3.69
Market-driven search strategy (factor)	1434	0.53	0.70	-1.73	2.55
Exploitative innovation strategy (factor)	1434	0.49	0.82	-2.80	2.46
Explorative innovation strategy (factor)	1434	0.31	0.99	-2.60	3.16
Firm size (log)	1434	4.17	1.59	1.79	12.95
R&D expenditure (1000 €)	1434	6.12	154.89	0	7627.74
Share of empl. with university qualifications (%)	1434	13.37	15.78	0	100
R&D collaboration (dummy)	1434	0.25	0.43	0	1
Geographic product market: local (dummy)	1434	0.23	0.42	0	1
Geographic product market: national (dummy)	1434	0.56	0.50	0	1
Geographic product market: EU (dummy)	1434	0.13	0.33	0	1
Geographic product market: other countries (dummy)	1434	0.08	0.28	0	1

Moreover, firms on average attach higher importance to a market-driven search strategy compared with a science-driven search strategy. Finally, it appears that firms in the sample are on average more exploitative than exploitative in their external search strategy.

4.1 Explorative and exploitative search strategies

Table 7 show the results of the Tobit estimation in the five model specifications with the innovation performance being the dependent variable. Beginning with the basic model (model A), both the parameters of depth and breadth are positive and significant, showing that the breadth and depth of openness of firm's innovative search are important factors in explaining innovative performance. The same conclusion was already reached by Laursen and Salter (2006).

Table 7: Tobit regression, explaining innovative performance across manufacturing firms: The effect of breadth and depth in dependence on explorative and exploitative search strategies

	Model A	Model B	Model C	Model D	Model E
Focus variables					
Breadth	0.0251**	0.0136	0.0308***	0.0293***	0.0136
Depth	0.281**	0.0796	0.295**	0.316**	-0.102
Explorative		-0.181**			0.240***
Exploitative			-0.121	-0.0413	
Breadth X explorative **H1**		0.0286*			
Depth X explorative					0.232
Depth X exploitative **H2**				0.0387*	
Breadth X exploitative			0.0117		
Control variables					
R&D expenditures	0.632*	0.493	0.631*	0.605*	0.487
Firm size	0.149***	0.153***	0.149***	0.150***	0.152***
Share of empl. with university qual.	0.00490***	0.00409**	0.00469***	0.00467***	0.00405**
R&D collaboration	0.164***	0.117**	0.158***	0.162***	0.117**
Geographic product market: national	0.157**	0.126*	0.153**	0.148*	0.128*
Geographic product market: EU	0.264***	0.220**	0.258***	0.257***	0.219**
Geographic product market: other countries	0.263**	0.218**	0.259**	0.255**	0.217**
Food	0.248**	0.282***	0.253**	0.253**	0.280***
Textile	0.15	0.164	0.145	0.146	0.167
Wood	0.451***	0.373**	0.452***	0.453***	0.367**
Oil, chemical	0.212**	0.236**	0.204*	0.205*	0.236**
Plastic, Rubber	0.209*	0.212*	0.209*	0.205*	0.214*
Non-Metallic minerals	0.249*	0.216*	0.247*	0.241*	0.218*
Primary metal	-0.0876	-0.04	-0.0827	-0.0818	-0.0424
Electronics	0.301***	0.315***	0.297***	0.294***	0.320***
Machines and equipment	0.327***	0.345***	0.325***	0.323***	0.348***
Cars, vehicle	0.262**	0.269**	0.258**	0.260**	0.270**
Furniture	0.207	0.172	0.21	0.212	0.176
Constant	-0.658***	-0.499***	-0.701***	-0.688***	-0.492***
sigma constant	0.669***	0.645***	0.667***	0.668***	0.644***
Log Likelihood	-1456	-1402.4	-1450.5	-1452	-1399.7
Chi-square	389***	491***	394.7***	391.8***	396.4***
Pseudo R^2	0.118	0.149	0.12	0.119	0.131
No. of obs	1434	1430	1430	1430	1430
No. of left-censored obs	399	397	397	397	397
No. of uncensored obs	1035	1033	1033	1033	1033

$* p < 0.05$, $** p < 0.01$, $*** p < 0.001$

With regards to our first hypothesis stating that the more explorative the objective of the firms, the more effective external search breadth will be on innovative performance, we do find evidence for this hypothesis (model B). The parameter of the interaction effect between external breadth search and explorative innovation objectives is positive and significant. That would mean that higher degrees of an explorative innovation strategy tend to favour the external breadth strategy. In contrast, the coefficient of the interaction effect between external breadth search and exploitive innovation objectives is insignificant (model C).

The second hypothesis affirming that the more exploitative the objectives of the firms, the more effective external search depth will be in shaping innovative performance can also be supported (model D). The coefficient for the interaction effect between external depth search and exploitative objectives is positive and significant, while the parameter for the interaction between external depth search and explorative objectives is insignificant (model E).

Regarding our control variables, we find -as expected- a positive effect of R&D expenditures on innovation performance. Moreover, performing R&D in collaboration with external actors, firm size, share of employees with university qualification and (wider) geographic product market have a positive and significant impact on the innovation performance.

4.2 Market-driven and science-driven orientation

The results of the effect of breadth and depth on innovation performance depending on market-driven and science-driven orientation are shown in Table 8.

Table 8: Tobit regression, explaining innovative performance across manufacturing firms: The effect of breadth and depth depending on market-driven and science-driven orientation

		Model A	Model B	Model C	Model D	Model E
Focus variables						
Breadth		0.0251**	0.0418**	0.0486***	0.0042	0.00368
Depth		0.281**	0.365**	0.334**	0.059	0.175
Science-driven			-0.0511	-0.206*		
Breadth X science-driven				0.0144		
Depth X science-driven	**H3**		0.0428*			
Market-driven					-0.0952	-0.195**
Breadth X market-driven	**H4**				0.0392*	
Depth X market-driven						0.25
Control variables						

	Model A	Model B	Model C	Model D	Model E
R&D expenditures	0.632*	0.49	0.501	0.602*	0.595
Firm size	0.149***	0.148***	0.147***	0.146***	0.147***
Share of empl. with university qual.	0.00490***	0.00506***	0.00517***	0.00501***	0.00503***
R&D collaboration	0.164***	0.189***	0.197***	0.190***	0.191***
Geographic product market: national	0.157**	0.162**	0.165**	0.168**	0.163**
Geographic product market: EU	0.264***	0.273***	0.279***	0.279***	0.270***
Geographic product market: other countries	0.263**	0.277***	0.280***	0.289***	0.284***
Food	0.248**	0.257***	0.258***	0.263***	0.264***
Textile	0.15	0.147	0.147	0.151	0.158
Wood	0.451***	0.449***	0.451***	0.467***	0.462***
Oil, chemical	0.212**	0.216**	0.212**	0.229**	0.236**
Plastic, Rubber	0.209*	0.213*	0.205*	0.220*	0.228*
Non-Metallic minerals	0.249*	0.250*	0.246*	0.265**	0.270**
Primary metal	-0.0876	-0.0783	-0.0736	-0.0687	-0.0644
Electronics	0.301***	0.319***	0.313***	0.318***	0.326***
Machines and equipment	0.327***	0.328***	0.326***	0.341***	0.342***
Cars, vehicle	0.262**	0.264**	0.261**	0.271**	0.277**
Furniture	0.207	0.2	0.196	0.211	0.217
Constant	-0.658***	-0.800***	-0.868***	-0.542***	-0.559***
sigma constant	0.669***	0.669***	0.669***	0.669***	0.668***
Log Likelihood	-1456	-1458.2	-1457.3	-1457	-1455.5
Chi-square-	389***	389.8***	391.6***	392.1***	395.2***
Pseudo R^2	0.118	0.118	0.118	0.119	0.12
No. of obs	1434	1434	1434	1434	1434
No. of left-censored obs	399	399	399	399	399
No. of uncensored obs	1035	1035	1035	1035	1035

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Our third hypothesis predicts that the science-driven orientation of the firm is complementary to the external search depth in shaping innovative performance. We find support of this hypothesis (model B). The coefficient of the interaction effect between external depth search and science-driven search variable is positive and significant, while the coefficient of the interaction between breadth and science-driven variable is insignificant (model C).

According to our fourth hypothesis, we expect that the market-driven orientation of the firm is complementary to the external search breadth in shaping innovative performance. We find evidence for this hypothesis (model D). The coefficient of the interaction effect between external breadth search strategy and market-driven orientation is positive and significant. By contrast, the interaction effect between depth and market-driven search is insignificant (model E).

5 Conclusions

We conducted this study to gain insights into how managers can optimise their search for external knowledge. Our goal is to investigate how companies actively address the dimensions of external knowledge search, i.e. breadth and depth.

By extending the analysis of external search strategies of Laursen and Salter (2006), we argue that the effectiveness of the search strategy (breadth and depth) for increasing innovation performance should depend upon two critical moderation factors: innovation objectives (explorative vs. exploitative innovation objective) as well as science-based or market-based orientation of the firms, when they drawing on external knowledge. Using the MIP data we found that external breadth is most effective when the firms are pursuing more explorative innovation objectives, while depth is more effective if the firms have more exploitative innovation objectives. Furthermore, we also find that breadth is more beneficial, when the firms obtain external knowledge from the market (market-based orientation), while depth is more effective when the firm have more of a science-based orientation.

From a managerial standpoint, we maintain that managers should take into consideration the exploitative/explorative innovation objectives of firms and the orientation of firms towards market/science. Specifically, in firms focussed more on explorative innovation objectives, managers should move away from depth towards supporting more breadth in external search strategies. Conversely, when a firm pursues exploitative innovation objectives, managers are on the right track well advised when they rely on an external depth strategy. Furthermore, managers should emphasise the external breadth search if the firm is more market-oriented in acquiring external knowledge and give more support to external search depth if the firm is more science-oriented.

For the future, significantly more research is required in order to create a greater understanding concerning the evolutionary process through which search strategies are planned, defined and permanently updated. This would appear possible if we had a panel dataset to control for changes in the external knowledge search strategies over time. Moreover, future studies should perhaps take into account the fact that the search strategies for external knowledge of young firms can be different from those of firms with considerable business experience and an established innovation management.

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Authors' affiliations

Younes Iferd
Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI)
Karlsruhe

Patrick Plötz
Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI)
Karlsruhe

Contact

Patrick Plötz
Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI)
Breslauer Strasse 48
76139 Karlsruhe
Germany
Phone: +49 721 6809-289
E-mail: patrick.ploetz@isi.fraunhofer.de
www.isi.fraunhofer.de

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