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Non-technical summary

Competitive advantage has frequently been shown to be the result of a firm's successful innovation activities. In this respect, it has almost become conventional wisdom that in-house research and development (R&D) is often not the only way to acquire new technological knowledge and create innovations. As the institutional loci of new technology can be diverse there is a high probability that at least from time to time firms need to source technological knowledge externally. In fact, many firms have shifted to a model of 'open innovation' that is characterized as involving a wide range of actors from the innovation system in the innovation process and exploiting their knowledge. External sources for innovation impulses like customers, suppliers, competitors or universities can subsequently be understood as the main elements of a firm's *search strategy,* which has been shown to have a substantial impact on innovation performance.

Research on the nature of these search strategies has largely focused on the dimensions of breadth and depth, where breadth designates the diversity and depth the intensity of search activities. There is, however, little evidence regarding the actual search direction. External knowledge impulses could, for instance, be rather market-driven (customers and competitors) or technology-driven (universities and other public research institutes). Insights on where to search for external knowledge and how effective this knowledge will be in enhancing innovation performance can thus be regarded as critical for the management of innovation processes. In other words, we argue in this paper that managers need to develop specialized search strategies to achieve innovation success. Moreover, the effectiveness of the search strategy for increasing innovation performance should depend upon two critical moderating factors: a firm's own investment in R&D as well as the potential of a firm's environment to provide external knowledge spillovers. Differences in the spillover potential of different countries might critically affect the potential value of a firm's innovation resources and capabilities.

Our research aims at extending existing literature by providing insights into the effectiveness of specialized search strategies of more than 5,000 firms from five Western European countries. Our analysis benefits from the unique opportunity to assemble innovation survey data across national and industry boundaries. We capture features of the innovation system and the industry. Based on tobit regression models we show that being open for innovation generally pays off. However, both moderating factors have a crucial role to play: On the one hand, in-house R&D is most effective when combined with a market-oriented search strategy. On the other hand, a technologically advanced environment requires firms to reach out to sources of scientific knowledge in order to access novel knowledge and to enhance innovation performance.

Das Wichtigste in Kürze

Bereits häufig konnte gezeigt werden, dass Wettbewerbsvorteile insbesondere das Ergebnis erfolgreicher Innovationstätigkeit eines Unternehmens sind. In diesem Zusammenhang ist es mittlerweile nahezu allgemein anerkannt, dass interne Forschungs- und Entwicklungstätigkeit nicht der einzige Weg zur Akquisition technologischen Wissens und zur Hervorbringung von Innovationen ist. Da die Quellen neuartiger Technologien sehr unterschiedlich sein können, ist es sehr wahrscheinlich, dass Unternehmen zumindest zeitweise technisches Wissen aus externen Quellen beziehen. Viele Unternehmen sind in der Tat zu einem „Open Innovation“-Modell übergegangen, das dadurch charakterisiert ist, dass es eine Vielzahl von Akteuren des Innovationssystems in den Innovationsprozess mit einbezieht und deren Wissen nutzt. Externe Quellen für Innovationsimpulse wie beispielsweise Kunden, Lieferanten, Wettbewerber oder Universitäten können daher als die wesentlichen Elemente der Suchstrategie eines Unternehmens betrachtet werden, die nachweislich einen wesentlichen Einfluss auf die Innovationsfähigkeit besitzt.

Bisherige Untersuchungen zum Thema Suchstrategien fokussierten maßgeblich auf die Dimensionen Tiefe und Breite, wobei die Breite die Vielfältigkeit und die Tiefe die Intensität der Suchstrategie kennzeichnet. Wenig ist allerdings über die Suchrichtung bekannt, die ein Unternehmen einschlagen sollte. Externe Wissensimpulse können beispielsweise eher marktorientiert (Kunden und Wettbewerber) oder technologieorientiert sein (Universitäten und andere Forschungseinrichtungen). Hinweise auf vielversprechende externe Wissensquellen und wie effektiv diese Wissensquellen dazu beitragen, den Innovationserfolg zu steigern, sind daher für das Innovationsmanagement von Unternehmen von hoher Bedeutung. Die vorliegende Studie entwickelt eine Argumentationskette dafür, dass Manager spezialisierte Suchstrategien entwickeln müssen, um Innovationserfolg zu erzielen. Darüber hinaus wird vermutet, dass die Effektivität einer Suchstrategie von zwei weiteren Faktoren abhängt: den eigenen Investitionen in Forschung und Entwicklung sowie dem Potenzial für Wissensspillovers des Umfeldes, in dem das Unternehmen tätig ist. Gerade die Unterschiede im Spillover-Potenzial unterschiedlicher Länder sollten den Wert der Ressourcen und Fähigkeiten des Unternehmens maßgeblich beeinflussen. Grund dafür sind die kombinativen Optionen mit firmenspezifischen Ressourcen.

Die vorliegende Untersuchung liefert Hinweise auf die Effektivität spezialisierter Suchstrategien für mehr als 5.000 Unternehmen aus fünf westeuropäischen Ländern. Auf Basis von Tobit-Regressionsmodellen wird gezeigt, dass sich ein „Open Innovation“-Ansatz generell positiv auf die Innovationsfähigkeit von Unternehmen auswirkt. Besondere Bedeutung kommt dabei jedoch den moderierenden Faktoren zu. So ist interne Forschung und Entwicklung insbesondere dann effektiv, wenn sie mit einer marktorientierten Suchstrategie kombiniert wird. Darüber hinaus erfordert ein technologisch fortgeschrittenes Umfeld eine Suchstrategie, die auf Universitäten und Forschungseinrichtungen gerichtet ist, da sich Unternehmen insbesondere von diesen einen Zugang zu neuartigem Wissen versprechen können.

Specialized Search and Innovation Performance – Evidence Across Europe

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Abstract

Searching for external knowledge has frequently been characterized as crucial for firm success. However, little is known about how the direction of search strategies influences innovation performance. In this paper, we argue that firms need to specialize their search strategy and that its effectiveness is moderated by R&D investments and potential knowledge spillovers from a firm's environment. Based on a sample of more than 5,000 firms from five European countries, our results show that being open for innovation generally pays off. However, both moderating factors have a crucial role to play: On the one hand, in-house R&D investments are most effective when combined with a market-oriented search strategy. On the other hand, a technologically advanced environment requires firms to reach out to scientific knowledge sources in order to access novel knowledge and to enhance innovation performance. We develop targeted management recommendations based on these results.

Keywords: Open innovation, search strategies, innovation management

JEL-Classification: L60, O32

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1 Introduction

Competitive advantage has frequently been shown to be the result of a firm's successful innovation activities (e.g., Banbury and Mitchell, 1995; Brockhoff, 1999). In this respect, it has almost become conventional wisdom that in-house research and development (R&D) is often not the only way to acquire new technological knowledge and create innovations. As the institutional loci of new technology can be diverse, there is a high probability that at least from time to time firms need to source technological knowledge externally (Teece, 1986; 1992). In fact, many firms have shifted to a model of 'open innovation' that is characterized as involving a wide range of actors from the innovation system in the innovation process and exploiting their knowledge (Chesbrough, 2003). External sources for innovation impulses like customers, suppliers, competitors or universities can subsequently be understood as the main elements of a firm's *search strategy,* which has been shown to have a substantial impact on innovation performance (Katila, 2002; Katila and Ahuja, 2002; Laursen and Salter, 2006).

Research on the nature of these search strategies has largely focused on the dimensions of breadth and depth (Katila and Ahuja, 2002; Laursen and Salter, 2006), where breadth designates the diversity and depth the intensity of search activities. There is, however, little evidence regarding the actual search direction. External knowledge impulses could, for instance, be rather market-driven (customers and competitors) or technology-driven (universities and other public research centers). Sources could be complementary or substitutive to each other. Insights on where to search for external knowledge and how effective this knowledge will be in enhancing innovation performance can thus be regarded as critical for the management of innovation processes. In other words, we argue in this paper that managers need to develop specialized search strategies to achieve innovation success.

Moreover, the effectiveness of the search strategy for increasing innovation performance should depend upon two critical moderating factors: firm's own investments in R&D as well as the potential of a firm's environment to provide external knowledge spillovers. Differences in the spillover potential of different countries might critically affect the potential value of a firm's resources and capabilities (Sirmon et al., 2007). Spillovers from the environment can support the growth of knowledge resources within a firm by providing access to complementary, external resources (Baum and Wally, 2003).

Our research aims at extending existing literature by providing insights into the effectiveness of specialized search strategies of more than 5,000 firms from five Western European countries. Our analysis benefits from the unique opportunity to assemble innovation survey data across national and industry boundaries based on the Community Innovation Survey (CIS). We capture features of the innovation system and the industry. Based on tobit regression models we show that being open for innovation generally pays off. However, both moderating factors have a crucial role to play: On the one hand, in-house R&D is most effective when combined with a market-oriented search strategy. On the other hand, a technologically advanced environment requires firms to reach out to sources of scientific knowledge in order to access highly novel knowledge and to enhance innovation performance.

The remainder of the paper is organized as follows: The next section provides a review of the relevant theory on external knowledge acquisition and open innovation and outlines our analytical framework. The third section describes our empirical strategy, followed by the results of our model. Implications for management are discussed in section 5. Section 6 ends with concluding remarks and avenues for further research.

2 Analytical framework

2.1 Searching for external knowledge sources

Firms increasingly use external knowledge as important sources for improving innovation performance and generating competitive advantage (Liebeskind, 1996). Recent research points to the emergence of a so called 'open innovation' paradigm (Chesbrough, 2003). The crucial role of external knowledge sources can be traced back to literature focusing on the resources and capabilities of firms (Barney, 1991; Conner, 1991; Peteraf, 1993; Wernerfelt, 1984), culminating in a knowledge-based perspective (Grant, 1996). Here, knowledge is viewed as a core element of a firm's capability to manage its resources and capabilities efficiently within an ever changing environment (Ndofor and Levitas, 2004). But, as knowledge has the character of a public good (Arrow, 1962; Jaffe, 1986), creating a competitive strategy around knowledge can be challenging. Firms are confronted with the risk that knowledge can 'spill over' to rival firms. Thus, firms must protect this valuable knowledge (Porter Liebeskind, 1997) which traditionally implies making use of secretive and self-contained in-house processes when producing knowledge through investments in R&D. However, recent literature has challenged this rather negative perception of knowledge spillovers between firms and their environment, emphasizing the potential benefits of acquiring external knowledge (Tsang, 2000). Instead of 'research and develop' the new paradigm can be termed as 'connect and develop' (Huston and Sakkab, 2006).

The shift towards a more open innovation process is driven by four interconnected factors (Chesbrough, 2003): first, an increasing availability and mobility of skilled workforce; second, the development of a venture capital market providing entrepreneurs with the capital necessary to develop and market new products; third, the emergence of new external market options for previously shelved inventions; and finally, the emergence of external suppliers with increasing capabilities. Openness challenges firms to reach out to actors beyond firm boundaries, in order to maximize the benefits from innovations and ideas (Rosenkopf and Nerkar, 2001). Research has revealed that the increasing integration of external knowledge at various levels of the innovation process is able to improve a firm's performance in several ways. Positive effects have been identified with regards to a firm's innovation success (Gemünden et al., 1992), an increase in the novelty of innovations (Amara and Landry, 2005) or higher returns on R&D investments (Nadiri, 1993).

More recent literature has referred to the targeted process of identifying promising external knowledge in a firm's environment as a firm's search strategy (Katila and Ahuja, 2002; Laursen and Salter, 2006). Search strategies can be conceptualized and classified in various ways. For example, Laursen and Salter (2006) have classified firms' search strategy according to their breadth and depth. The breadth of a search strategy is measured by the diversity (broadness) of external inputs. A broad search strategy is likely to reduce a firm's risk from unpredictable developments, but also entails that the information-processing capacities are limited. Search depth is defined as to how extensively firms draw on external sources for innovation inputs (Laursen and Salter, 2006). Both dimensions (breadth and depth) characterize a firm's openness to external knowledge. The relationship between searching widely and deeply and innovation performance can take on an inverted U-shape, as found by Laursen and Salter (2006) in their study of UK manufacturing. Thus, while search efforts initially increase performance, there is a turning point from where firms risk impeding their performance by 'over-searching' their environment.

A related approach is applied by Katila and Ahuja (2002). The authors examine how firms search and solve problems by focusing on two dimensions: search scope and search depth. Search scope defines how widely a firm explores external knowledge, and search depth is defined as the extent to which a firm reuses existing knowledge. While the former concept largely matches the concept of search breadth, the latter points more to the exploitation of the established knowledge base. Katila and Ahuja (2002) find an inverted U-shaped relationship between a firm's search behavior and innovation performance as well, revealing the negative effects of overly extensive search activities. They also show that the interaction of search scope and depth is positively related to innovation performance: A unique combination of a deep understanding of firm-specific knowledge assets combined with new applications (scope) can serve as a profitable basis for commercialization.

As a consequence, the goal of this study is to go beyond the dimensions of breadth and depth in a firm's search strategy. Our central premise is that innovation managers will not randomly choose different sources to broaden and/or deepen their search strategies. Instead, we argue that synergies between different knowledge sources can be identified which managers selectively exploit. Our analytical approach has therefore three major elements. In an initial, explorative step we identify the underlying factors of firm's search strategies. Secondly, we relate these actual practices to innovation success. Finally, we explore differences in firm's own R&D investment and the technological opportunities in their home countries as mediating factors to derive more detailed implications for management.

2.2 Specialization in search strategies

Literature identifies several potentially valuable sources of knowledge in a firm's environment. Many studies point predominantly to customers, suppliers, competitors and/or universities (see for example Frost et al., 2002). These sources differ significantly in the type of knowledge they can provide and how easily it can be accessed.

Customers have been identified as a particularly promising source of knowledge, especially when their demand is anticipatory for broader market segments. Von Hippel (1988) refers to this subgroup as lead users. However, these lead users may be difficult to find. Frosch (1996) points out that incorporating customer impulses into innovation projects is generally risky. Their impulses can be myopic, narrow and frequently wrong. Even when these leading customers can be identified, accessing their knowledge is challenging. Their knowledge is often times tacit or unarticulated (Von Zedtwitz and Gassmann, 2002). These knowledge attributes make it difficult to separate customer knowledge from its original context and transfer it completely and efficiently. In other words, the knowledge remains "sticky" (Szulanski, 1996). Conversely, valuable competitor knowledge is generally easier to identify because it is largely embedded in tangible products on the market. Competitors operate in a similar market and technology context which makes their impulses immediately relevant and easier to absorb (Dussauge et al., 2000). However, the degree of novelty and hence the potential for commercial exploitation of competitor knowledge may be limited because opportunities for product differentiation based on shared knowledge among competitors are limited. Using competitors as the primary source of external knowledge may therefore be more closely related to an imitation strategy. Knowledge produced in universities and academic research institutions provides important business opportunities because of the high degree of novelty (Cohen et al., 2002). The knowledge produced in these academic institutions however may be far from application and typically requires substantial investments into developing final products (Link et al., 2006; Siegel et al., 2004). What is more, accessing university knowledge can be difficult. Incentive systems for private and university researchers with regards to publishing or protecting research results vary significantly and can generate barriers to knowledge acquisition (Perkmann and Walsh, 2007). Supplier knowledge may be more easily accessible because it is embodied in the novel materials or equipment they provide. Having access to these inputs may subsequently enable firms to generate innovative products themselves (Pavitt, 1984). However, their knowledge may also become easily available to major competitors and loose its uniqueness. Finally, knowledge impulses may also be rather freely available from conferences, trade fairs or scientific and industry publications. This knowledge is also available to competitors but there exist almost no barriers to accessing this knowledge, making it attractive as an instrument to get a rather quick overview of available knowledge in a technology field or industry.

In conclusion, the various sources of knowledge provide different opportunities and challenges for designing search strategies. We argue that innovation managers will choose specialized search strategies balancing fruitful diversity in potential knowledge impulses with the efficiency of access. Search strategies are thus the reflection of targeted management choices on which sources to target and activate (Gottfredson et al., 2005; Stock and Tatikonda, 2004). Todorova and Durisin (2007) find that a major challenge for absorbing external knowledge lies in the necessary transformation so that it will fit into a firm's existing knowledge stock. We argue that innovation managers will design search strategies that minimize these transformation costs by focusing on certain knowledge sources with similar characteristics. While we cannot explicitly predict this specialization in search strategies we suspect that most firms distinguish between market related knowledge from customers and/or competitors and technological knowledge from universities and/or suppliers.

2.3 The moderating role of firm's own R&D investments and its knowledge environment

Searching for external knowledge sources is not practiced as an end in itself but should improve innovation performance of a firm. We consider two major moderating factors for the success of specialized search strategies: First, firm's in-house investment in knowledge production through research and development. It is intended to increase a firms' stock of knowledge. However, as Cohen and Levinthal (1989) point out these learning engagements also increase the firm's ability to identify, assimilate and exploit external knowledge. Cohen and Levinthal (1989; 1990) describe this as a firm's absorptive capacity. Absorptive capacities are built through a firm's organizational routines and processes (Zahra and George, 2002). Generally, absorptive capacities are created as a by-product of R&D activities (Cohen and Levinthal, 1989; 1990). They can be regarded as a firm's dynamic capability to refocus its knowledge base through iterative learning processes (Szulanski, 1996; Zahra and George, 2002). An innovating firm needs to engage in continuous learning engagements with the objective to sense market and technology trends and to translate them into pre-emptive actions. Absorptive capacities enable firms to draw from a wider set of diverse knowledge, and thereby offering more options for solving problems and coping with environmental change (Bowman and Hurry, 1993; March, 1991). Thus, firms can combine valuable or rare resources, engage in exploratory innovation activities (Jensen et al., 2007; Subramaniam and Youndt, 2005) and predict future developments more accurately (Cohen and Levinthal, 1994). Investment in in-house R&D may therefore generate absorptive capacities and form the basis for a firm's search strategy. Hence, a theoretical link can be established between the R&D investments of a firm and its search strategy. However, building these capabilities typically requires substantial time and resource commitments which limit a firm's ability to pursue alternative options (Sapienza et al., 2006). Firms establish an innovation trajectory through investments in physical laboratories and specialized scientists and engineers. These investments are supposed to provide the best fit for identifying and exploiting opportunities in a particular field. However, this specialization generates necessarily a certain level of lock-in as it limits a firm's ability to pursue alternative technological routes (see for example Levinthal and March, 1993). Hence, we conclude that the returns on the investments into own R&D will differ with regards to innovation success. We suspect that some specialized search strategies will outperform others given a certain investment into own R&D.

Secondly, we argue that a firm's innovation environment significantly influences the effectiveness of specialized search strategies. The reason for this is that knowledge created by R&D activities is likely to spill over. Arrow (1962) argued that spillovers occur during the production and use of new knowledge as a result of indivisibilities in both inputs and outputs, uncertainty, low appropriability, and lack of excludability. Hence, knowledge has characteristics of a public good. A substantial body of literature has focused on the importance of knowledge spillovers for generating economic growth (e.g., Romer, 1990; Jaffe, 1989; Acs et al., 1992, 1994; Feldman, 1994; Audretsch and Feldman, 1996). In this context, many studies have pointed to the role of localised spillovers from relevant knowledge sources that result from proximity facilitating communication and learning (e.g., Jaffe, 1989;

Feldman, 1994; Audretsch and Feldman, 1996). Hence, a firm's search strategy should reflect its environment and the opportunities to benefit from spillovers.

As a consequence, the spillover potential of a firm's environment might critically affect the potential value of a firm's resources and capabilities. Moreover, spillovers can support the growth of resources within firms by providing access to complementary, external knowledge (Baum and Wally, 2003). Thus, the success of a firm's specialized search strategy may be altered by the characteristics of the local knowledge environment (Grimpe and Sofka, 2009; Van den Bosch et al., 1999). We define this local environment more narrowly as the degree of technological opportunity in the home country of the firm which influences the extent to which specialized search strategies contribute to innovation success.

3 Empirical strategy

3.1 Data

The empirical part of this analysis is based on cross-sectional data from the third *Community Innovation Survey* (CIS-3), a survey which was conducted under the coordination of Eurostat in 2001. It is directed at the innovation activities of enterprises in the EU member states (including all ascending and some neighbouring states) with at least ten employees. For the 2001 survey, data refer to innovation activities in the three-year period from 1998 to 2000. General managers, heads of R&D departments or leading innovation managers are asked directly if and how they are able to generate innovations. CIS provides a wealth of information that is particularly relevant to our research questions. CIS-3 data have only recently been released by Eurostat in the form of anonymized data. The CIS-3 anonymization method applied by Eurostat is based on a micro-aggregation process which modifies the firm level data in such a way that individual firms can no longer be identified, i.e. it is not possible to match a firm with its exact responses (Eurostat, 2005). Nevertheless, the usefulness of CIS can be evaluated based on a comparison of anonymized and non-anonymized micro-data. This consistency check yielded a satisfactory performance for Germany, in that the data can consistently be used to reveal structural relationships among the survey variables (Gottschalk and Peters, 2009).

Although CIS-3 was performed in each EU member state, country data availability is restricted due to confidentiality concerns and individual contracts between the member states and Eurostat. Data is available for 12 European countries only. We restrict the sample further to countries with established market economies and exclude all transition economies. The reason for this exclusion are substantial differences in the innovation systems of established market economies and transition economies, leading to a possible bias in the discussion of the environmental munificence. Table 1 shows the composition of the sample by country.

Table 1: Number of observations per country

Country	Number of observations
Belgium	640
Germany	1,526
Greece	338
Portugal	505
Spain	2,073
Total	5,082

CIS has a number of features taking into account the self-reported and largely qualitative character of the survey (for a recent discussion see Criscuolo et al., 2005). First, CIS-3 was administered via mail which prevents certain shortcomings and biases of telephone interviews (Bertrand and Mullainathan, 2001). The European application of CIS adds extra layers of quality management. CIS is subject to extensive pre-testing and piloting in various countries, industries and firms with regards to interpretability, reliability and validity (Laursen and Salter, 2006). Moreover, the questionnaire contains detailed definitions and examples to increase response accuracy. Overall, this immediate information on processes and outputs can complement traditional measures for innovation such as patents (Kaiser, 2002; Laursen and Salter, 2006).

3.2 Measures

Measuring innovation performance

Several concepts have been discussed in the literature for capturing innovation performance (for an overview see OECD, 2005). While some concepts focus on innovation inputs (R&D expenditure), others focus at the consequences of innovation activities, e.g. patents, new processes and products. We adopt the latter perspective. A firm innovation success critically depends on the market acceptance of new products. Hence, we measure innovation performance as the share of turnover generated with new products. More specifically, these new products have to qualify as market novelties and not just as new to the firm. This measure is more closely related to radical innovation performance. As a result, we take the share of turnover with market novelties[1] as our dependent variable in line with several other studies in the field (e.g. Laursen and Salter, 2006).

Capturing specialized search strategies

Measuring knowledge spillovers is a challenging task since they leave no paper trail. Therefore, several studies in the field have relied on patent statistics and subsequent citations to capture them (e.g., Galunic and Rodan, 1998; Rosenkopf and Nerkar, 2001). This approach has several disadvantages. Most importantly, "not all inventions are patentable, not all inventions are patented" (Griliches, 1979: p.1669). What is more, the distribution of patenting firms is heavily skewed. Bloom and Van Reenen (2002) illustrate this, with 72 per cent of

[1] By definition a market novelty is a novelty on a firm's relevant market and not necessarily a "new to the world" innovation.

their sample of almost 60,000 patents by UK firms stemming from just 12 companies. Patenting implies the disclosure and codification of knowledge in exchange for protection (e.g. Gallini, 2002). The majority of valuable knowledge may therefore never be patented. Most importantly for this study, patent citation statistics cannot reveal the relationship between two firms (e.g. whether they are customers or competitors). Thus, the opportunities for pattern recognition are limited. Consequently, we rely on survey questions 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 for their innovation activities on a 4-point Likert scale ranging from "not used" to "high". Following Laursen and Salter (2006) we use seven different sources: suppliers, customers, competitors, universities, research institutes, professional conferences (including meetings and journals) as well as trade fairs. We conduct an exploratory principal-component factor analysis to identify a firm's specialization in a particular search strategy.

The Kaiser-Meyer-Olkin measure of sampling adequacy shows a satisfactory value of 0.70. We are able to retain three factors with an Eigenvalue larger than one. Table 2 shows the rotated factor loadings of the knowledge sources. For better readability, factor loadings smaller than .5 were excluded from the table. The scale reliability coefficients (Cronbach's alpha) were only calculated for the main variables with a loading on the three factors greater than 0.7. They can be regarded as satisfactory. The main variables constituting the factor also serve as focal points for the interpretation of the factors.

Table 2: Rotated factor loadings

Knowledge source	Factor 1: Science-driven	Factor 2: Market-driven	Factor 3: Supply-driven	Uniqueness
Suppliers			0.70	0.51
Customers		0.85		0.27
Competitors		0.81		0.30
Universities	0.87			0.22
Research centers	0.87			0.23
Conferences			0.70	0.37
Trade fairs			0.76	0.33
Cronbach's alpha	0.72	0.61	0.61	

Factor loadings smaller than .5 are not displayed.

It turns out that the externally available knowledge sources can be condensed to three factors depicting a science-driven search strategy using knowledge from universities and public research centers as well as a market-driven search strategy combining customer and competitor impulses. Finally, a supply-driven search strategy can be identified that focuses on suppliers, conferences and trade fairs. Conferences and trade fairs can be assumed to serve as an instrument where contacts can be established with a variety of potential other suppliers allowing firms to acquire knowledge from these sources.

Moderating factors

We suggest two moderating factors between search strategies and a firm's own R&D investment and another one with a firm's national, technological environment. The rational for the first interaction was derived from the literature on absorptive capacities which are typically assumed to be a by-product of performing R&D activities. In line with the literature (Cohen and Levinthal, 1989) we capture this effect through a firm's expenditure for R&D as a share of sales. R&D expenditure can only partly capture a firm's absorptive capacity as significant fractions of it may be directed towards direct knowledge production within the firm. Accumulated knowledge stocks can be considered a more appropriate operationalization. Within an anonymzed dataset we have no opportunity to generate such variables (e.g. patent stocks). This shortcoming should be kept in mind when interpreting the results. Then again, R&D intensity has been a core element of some of the most prominent studies on the relationship between external learning and innovation success from early, groundbreaking research (e.g. Cohen and Levinthal, 1989, 1990) to most recent applications (e.g. Laursen and Salter, 2006). R&D intensity will subsequently be interacted with the specialized search strategies. Other authors have hinted toward other elements of a firm's absorptive capacities, such as continuous R&D activities in dedicated departments or formal education level of its employees (see for example Rothwell and Dodgson, 1991). We will control for both factors. First, we include a dummy variable indicating whether R&D activities are performed continuously. To capture the available human capital we include the ratio of employees with college education over sales.

The second moderating effect relates to a firm's local environment. We follow Arrow (1962) who assumes that localized knowledge spillovers are more important in highly R&D intensive environments. Hence, we measure the spillover potential as the percentage of R&D on a country's gross domestic product (GERD) for the five European countries under study. The source for these data is the OECD's statistics on Main Science and Technology Indicators (MSTI). GERD depict the research orientation of an economy. This measure could be regarded as rather coarse but it reflects the availability of knowledge spillovers that firms may be able to benefit from in their national environment. It includes both business R&D expenditure as well as government-funded R&D expenditure in universities and public research centers.

Control variables

We add control variables for several other factors that may influence the estimation results. Firms may suffer from a liability of size or smallness. We capture these factors by including a firm's sales from the start of the reporting period (1998) in logs. In addition, we control for a firm's degree of internationalization by incorporating the ratio of exports to total turnover. Moreover, in two model specifications we include country dummies. Finally, we include industry dummies in terms of industry groups as defined in the classification of the OECD (2006).

3.3 Estimation method

We use tobit models to estimate the determinants of innovation performance. This estimation method reflects the characteristics of our dependent variable which is measured as a percentage of total sales and hence exhibits a minimum of 0 and a maximum of 100. It is not unlikely for a firm to have no sales with market novelties. Tobit models adequately account for such censoring of the data.

4 Results

Table 3 shows the descriptive statistics. It turns out that on average firms are able to achieve 10 percent of their sales with market novelties. Moreover, firms attach on average a higher importance to a supply- and market-driven search strategy compared with a science-driven search strategy.[2] Firms spend 2 percent of their sales on average for R&D. Finally, the average spending of a country for R&D (GERD) equals 1.54 percent with a minimum of 0.61 percent and a maximum of 2.52 percent.

Table 3: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Share of sales with market novelties (ratio)	5082	10.08	17.99	0	100
Science-driven search strategy (factor)	5082	0.62	0.81	0	3
Market-driven search strategy (factor)	5082	1.47	0.93	0	3
Supply-driven search strategy (factor)	5082	1.47	0.79	0	3
Share of R&D exp. of sales (ratio)	5082	0.02	0.08	0	1
Cont. R&D activities (d)	5082	0.42	0.49	0	1
Share of empl. with college educ. (ratio)	5082	0.00	0.01	0	0.19
Sales 1998 (log)	5082	15.98	2.01	6.91	23.99
Share of sales w/ exports (ratio)	5082	0.21	0.28	0	1.00
GERD as a percentage of GDP (ratio)	5082	1.54	0.72	0.61	2.52
Other manufacturing (d)	5082	0.01	0.09	0	1
Medium-tech manufacturing (d)	5082	0.39	0.49	0	1
High-tech manufacturing (d)	5082	0.06	0.23	0	1
Other services (d)	5082	0.10	0.31	0	1
Knowledge-intensive services (d)	5082	0.18	0.38	0	1

Variables are checked for multicollinearity. Table 6 in the appendix reports the pairwise correlations. Moreover, the mean variance inflation factor (VIF) equals 1.52 and the condition number equals 29.13. We can conclude that multicollinearity does not present a challenge for our data (Belsley et al., 1980).

Table 4 shows the results of the tobit estimations in three different model specifications with the innovation performance being the dependent variable. Focusing on the three search strategies in the base model it turns out that both the science- and the supply-driven search strategies have a positive and significant effect on innovation performance. There are no significant differences between them. This result underlines the importance of opening up the innovation process particularly into these directions. Moreover, we can observe a strong positive and significant effect of internal R&D intensity on innovation performance. As a result, internal R&D as well as external knowledge sources can be assumed to be jointly important for innovation performance.

[2] Factor scores have been rescaled to fit on the scale of the individual items ranging from 0 (no importance) to 3 (high importance).

The second model shifts the emphasis on the effects of three interaction terms consisting of the search strategies and the firm's R&D intensity. The resulting coefficients show whether there is an extra effect from a combination of a particular search strategy with internal R&D activities. In other words, the interaction effects show whether internal R&D investments are particularly valuable when combined with a specialized search strategy. First of all, it turns out that the positive and significant effects of the two search strategies are robust in this model specification, as is the internal R&D intensity. Focusing on the interaction terms, our results show that internal R&D activities are particularly valuable when combined with a search strategy oriented towards market knowledge, i.e. the knowledge of customers and/or competitors. Neither a science nor supply driven search strategy provides an extra benefit for innovation performance on top of the additive effects.

The third model specification leaves the country dummies out but includes the country GERD as a percentage of GDP as a measure for the spillover potential. In this specification, only the supply-driven search strategy is positive and significant. The positive effect of the internal R&D intensity remains robust. Our proxy for the spillover potential exhibits a negative coefficient, i.e. the more technologically advanced the environment, the more difficult it is for firms to achieve sales with market novelties. This finding suggests a strong technology-oriented competition from rival firms which are eager to launch new products to the market themselves. Corresponding with this finding, our results show a positive effect of the interaction term between the science-driven search strategy and the country GERD. This means that in technologically sophisticated environments it will be most beneficial for firms to reach out to universities and public research centers in order to access highly novel technological knowledge.

Finally, significant results for the control variables will be highlighted. Continuous R&D activities, often times associated with having a dedicated R&D department, prove to be beneficial for innovation performance in all three model specifications. Firm size (sales in 1998) can be shown to have a robust negative effect on performance, i.e. the smaller a firm, the higher its innovation success as a share of overall sales. The export intensity of the firm which serves as a proxy for its international orientation turns out to be positively associated with performance across the specifications. Results for the industry dummies can be found in Table 5 in the appendix.

Table 4: Marginal effects of tobit estimations for innovation performance

	Base model	Interaction model R&D	Interaction model GERD
Science-driven search strategy (factor)	0.31*	0.36**	-0.52
	(0.17)	(0.17)	(0.37)
Market-driven search strategy (factor)	0.27	0.15	0.05
	(0.16)	(0.17)	(0.37)
Supply-driven search strategy (factor)	0.38**	0.37**	0.67*
	(0.16)	(0.16)	(0.36)
Share of internal R&D exp. of sales (ratio)	8.64***	10.21***	8.77***
	(1.99)	(2.61)	(1.98)
Cont. R&D activities (d)	3.67***	3.61***	3.60***
	(0.38)	(0.38)	(0.38)
Share of empl. with college educ. (ratio)	2.27	-2.93	3.22
	(26.08)	(26.23)	(26.10)
Sales 1998 (log)	-0.37***	-0.36***	-0.31***
	(0.09)	(0.09)	(0.09)
Share of sales w/ exports (ratio)	1.79***	1.69***	1.28**
	(0.65)	(0.66)	(0.62)
Spain (d)	3.57***	3.54***	
	(0.56)	(0.56)	
Germany (d)	1.61***	1.60***	
	(0.58)	(0.58)	
Greece (d)	2.64***	2.62***	
	(0.93)	(0.93)	
Portugal (d)	4.66***	4.65***	
	(0.83)	(0.83)	
Interaction science-driven * R&D intensity		-1.22	
		(1.29)	
Interaction market-driven * R&D intensity		4.46**	
		(1.81)	
Interaction supply-driven * R&D intensity		0.79	
		(1.79)	
Interaction science-driven * GERD			0.56***
			(0.22)
Interaction market-driven * GERD			0.19
			(0.23)
Interaction supply-driven * GERD			-0.19
			(0.22)
GERD as a percentage of GDP (ratio)			-1.43***
			(0.24)
Industry dummies	Yes	Yes	Yes
Constant (coeffcient)	0.59	0.33	12.09***
	(4.27)	(4.28)	(3.97)
Aldrich-Nelson Pseudo R2	0.07	0.08	0.07
Number of observations	5082	5082	5082
LR/Wald chi2	341.46	349.00	320.55
P-value	0.00	0.00	0.00

(d) for discrete change of dummy variable from 0 to 1. * p<0.10, ** p<0.05, *** p<0.01
Belgium serves as the reference group.

5 Discussion and implications for management

We conduct this study to investigate the search strategies of firms within an open innovation framework. Previous work has conceptualized these search strategies along the dimensions of the breadth and depth of the knowledge sources they include (Laursen and Salter, 2006). Our goal is to go beyond this approach and identify structures within the various sources which would indicate a specialization of search strategies. This follows the basic rationale that innovation managers will not randomly combine knowledge sources but choose a specialized approach reflecting similar opportunities and challenges for identifying, absorbing and assimilating this knowledge. We identify these specialization structures within a unique dataset of more than 5,000 firms from five Western European countries based on a harmonized survey.

We find three types of specialization in firm's search strategies. These reflect market knowledge (customers, competitors), scientific knowledge (universities, research institutions) and supplier knowledge (suppliers, conferences, trade fairs, journal articles). Hence, the underlying knowledge sources may just reflect that firms have developed targeted search strategies for accessing them, i.e. a specialization on market knowledge but not individual ones for customer or competitor knowledge. It turns out that science- and supply-driven search strategies foster innovation success, with a market-driven search strategy being important when combined with in-house R&D investments. In that sense, our study supports the work of Laursen and Salter (2006) and Katila and Ahuja (2002).

Interesting distinctions emerge once we consider moderating factors. We find that a firm's own investment in R&D has a positive effect on innovation success. However, the on-top-effect of combining R&D activities with a certain search strategy are limited to market knowledge only. Apparently, directing R&D activities towards customer needs or competitor pressures leads to innovation success. Our database is cross-sectional in nature. Hence, long-term effects from targeting for example scientific knowledge cannot be detected.

Moreover, our dataset allows us to test the results in different national environments. We argue conceptually that the knowledge spillover potential in a firm's national environment influences the effectiveness of its search strategies. We find strong support for this. Apparently, targeting scientific knowledge turns out to be more valuable in technologically advanced nations.

Both moderating effects allow us to derive management implications. First, most literature advises innovation managers to develop close links with key customers (e.g. Day, 1994), universities (e.g. Schartinger et al., 2002) or suppliers (e.g. Kotabe et al., 2003). We find strong support for developing specialized search strategies for these knowledge sources. Innovation managers may distinguish themselves in competition on the one hand through exclusive access to certain knowledge but on the other hand by their abilities to find the valuable parts within an enormous amount of potentially available knowledge, extract the relevant elements to transform and assimilate them with existing knowledge stocks. This underlines the importance of own R&D investments as driver of absorptive capacity (Cohen and Levinthal, 1990). Another important message from our findings is that specialized search for knowledge from science is especially relevant in high-technology environments. In these environments the knowledge pools from leading customers, competitors or suppliers may not sufficiently provide the firm with a competitive edge. Hence, as countries become more technologically sophisticated opportunities for science-driven search strategies arise. This may be an important time to switch or extend search strategies in emerging economies and supplement the publicly available knowledge sources.

Besides, we find that all specialized search strategies as well as own R&D investments increase innovation success. A multiplicative relationship, though, can only be identified for the combination of own R&D intensity and market-driven search strategies. In that sense, innovation managers can maximize the immediate returns from increasing their R&D budgets if they connect it with a primary focus on customer needs or competitor pressures. This may include intensifying market screening and scouting activities as primary triggers for new R&D projects or entering joint development projects with leading customers. All other specialized search strategies cannot generate a similar multiplicative effect. Then again, this can also be interpreted as a positive sign for firms with resource limitations on their R&D budgets. Our results indicate that the benefits from science- and supply-driven search strategies are not directly related to a firm's own R&D investments. Instead, innovation management may be able to substitute own R&D with these external impulses. This effect is not feasible, though, when applying a specialized market search strategy because the multiplier effect would inflate the effects of the cutbacks in own R&D.

6 Concluding remarks and further research

This research aims at addressing an important gap in the literature on how search strategies are shaped. We identify underlying structures of specialization in a firm's search strategy and their effects on innovation success. Nevertheless, much more research is needed in order to achieve a more detailed and fine-grained understanding about the evolutionary process through which search strategies are defined and continuously updated. This would require a panel data set to control for changes in the internal and external factors over time.

Moreover, it is sensible to argue that search strategies could also depend upon the maturity of the firm. In other words, search strategies of young firms should be different from those firms with considerable business experience. Accordingly, the importance of internal and external factors should vary with firm maturity.

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Appendix

Table 5: Estimation results for industry dummies

	Base model	Interaction model R&D	Interaction model GERD
Other manufacturing (d)	-1.64	-1.67	-1.66
	(1.71)	(1.71)	(1.72)
Medium-tech manufacturing (d)	0.31	0.32	0.24
	(0.41)	(0.41)	(0.41)
High-tech manufacturing (d)	1.70**	1.61**	1.74**
	(0.77)	(0.77)	(0.77)
Other services (d)	-0.09	-0.11	-0.37
	(0.61)	(0.61)	(0.60)
Knowledge-intensive services (d)	1.97***	1.95***	1.85***
	(0.58)	(0.58)	(0.57)

Table 6: Correlation matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
1. Science-driven strategy	1.00																
2. Supply-driven strategy	0.00	1.00															
3. Market-driven strategy	0.00	0.00	1.00														
4. R&D intensity	0.22	0.02	0.04	1.00													
5. Continuous R&D	0.33	0.06	0.16	0.26	1.00												
6. Skilled employees	0.10	0.01	0.02	0.29	0.08	1.00											
7. Sales 1998	0.19	0.01	0.11	-0.11	0.29	-0.22	1.00										
8. Export intensity	0.14	0.00	0.11	0.01	0.26	-0.11	0.27	1.00									
9. Other manufacturing	0.04	0.00	0.00	-0.02	-0.03	-0.01	0.07	-0.07	1.00								
10. Medium-tech manuf.	0.05	-0.01	0.06	-0.08	0.12	-0.14	0.09	0.26	-0.07	1.00							
11. High-tech manuf.	0.06	0.00	0.10	0.07	0.15	0.01	-0.01	0.09	-0.02	-0.20	1.00						
12. Other services	-0.11	-0.04	-0.03	-0.08	-0.17	-0.05	0.02	-0.15	-0.03	-0.28	-0.09	1.00					
13. Knowledge-intensive serv.	0.10	-0.04	0.03	0.28	0.05	0.35	-0.06	-0.22	-0.04	-0.37	-0.12	-0.16	1.00				
14. Spain	0.03	-0.06	-0.08	0.06	-0.01	0.03	-0.05	-0.05	-0.01	-0.06	0.05	-0.12	-0.03	1.00			
15. Germany	0.05	0.04	0.22	-0.01	0.11	-0.01	0.20	-0.04	0.04	0.05	0.01	0.06	0.08	-0.54	1.00		
16. Greece	-0.08	0.05	-0.09	-0.08	-0.09	0.05	-0.18	-0.20	-0.02	-0.03	-0.06	0.01	-0.02	-0.22	-0.17	1.00	
17. Portugal	-0.06	0.03	-0.09	-0.07	-0.11	-0.04	-0.08	0.04	0.01	0.00	-0.04	0.01	-0.08	-0.28	-0.22	-0.09	1.00