Sofka, Wolfgang; Grimpe, Christoph

Working Paper

Managing Search Strategies for Open Innovation: The Role of Environmental Munificence as well as Internal and External R&D

ZEW Discussion Papers, No. 08-075

Provided in cooperation with:
Zentrum für Europäische Wirtschaftsforschung (ZEW)

Suggested citation: Sofka, Wolfgang; Grimpe, Christoph (2008) : Managing Search Strategies for Open Innovation: The Role of Environmental Munificence as well as Internal and External R&D, ZEW Discussion Papers, No. 08-075, http://hdl.handle.net/10419/27553

Discussion Paper No. 08-075

Managing Search Strategies for Open Innovation – The Role of Environmental Munificence as well as Internal and External R&D

Wolfgang Sofka and Christoph Grimpe

ZEW
Zentrum für Europäische Wirtschaftsforschung GmbH
Centre for European Economic Research

Discussion Paper No. 08-075

Managing Search Strategies for Open Innovation – The Role of Environmental Munificence as well as Internal and External R&D

Wolfgang Sofka and Christoph Grimpe

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. In order to define an appropriate search strategy, however, firms need to have developed the ability to recognize the potential value of external knowledge sources. In other words, the *absorptive capacity* of firms has a crucial role to play.

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. Moreover, the search strategy should reflect the environment. It has been suggested that its effectiveness depends on environmental munificence. The varying munificence of environments might critically affect the potential value of a firm's resources and capabilities. Moreover, munificent environments can support the growth of resources within firms by providing access to complementary, external resources. As a consequence, the munificence of the environment as well as firm-level factors are likely to influence the choice of search strategies. Little is known, however, what factors lead to such a choice, and determine the breadth and depth of a firm's search strategy. Our research aims at extending existing literature by providing insights into the search strategies of more than 8,300 firms from twelve European countries.

Based on tobit regression models we show that the factors determining breadth and depth of search strategies vary considerably. It turns out that internal R&D favors deeper over broader search strategy while external R&D provides the firm with the access to a higher diversity of external knowledge which in turn implicates higher breadth. A munificent innovation system allowing for knowledge spillovers turns out to enable firms to higher search breadth. Our findings have implications for management in that we provide recommendations on how to shape the search breadth and depth of a firm.

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 häufig nicht der einzige Weg zur Akquisition technischen Wissens und zur Schaffung von Innovationen darstellt. Da die Quellen neuartiger Technologien sehr unterschiedlich sein können, ist es sehr wahrscheinlich, dass Unternehmen zumindest zeitweise technisches Wissen extern beziehen. Viele Unternehmen sind in der Tat zu einem „Open Innovation" Modell übergegangen, dass dadurch charakterisiert ist, dass es eine Vielzahl von Akteuren des Innovationssystems in den Innovationsprozess mit einbezieht und deren Wissen ausnutzt. Externe Quellen der Innovationsimpulse, wie beispielsweise Kunden, Lieferanten, Wettbewerber oder Universitäten, können anschließend als die wesentlichen Elemente der Suchstrategie eines Unternehmens betrachtet werden, was nachweislich einen wesentlichen Einfluss auf die Innovationsfähigkeit besitzt. Um eine angemessene Suchstrategie zu definieren, müssen die Unternehmen indes die Fähigkeit entwickeln, den potenziellen Wert einer externen Wissensquelle anzuerkennen. Mit anderen Worten fällt der absorptiven Kapazität eines Unternehmens eine zentrale Rolle zu.

Forschung zu Suchstrategien Forschungsstrategien fokussiert maßgeblich auf die Dimensionen der Tiefe und Breite – wobei die Breite die Vielfältigkeit und die Tiefe die Intensität der Forschungsstrategie kennzeichnet. Darüber hinaus sollte die Suchstrategie das Wissensumfeld der Unternehmung widerspiegeln. Ein attraktives Umfeld kann das Wachstum der Ressourcen innerhalb eines Unternehmens durch den Zugang zu komplementären, externen Ressourcen unterstützen

Indes gibt es wenig Wissen darüber, welche Einflussfaktoren zu einer solchen Wahl führen und damit die Breite und Tiefe der Suchstrategie einer Firma determinieren. Unsere Forschung hat zum Ziel, die bestehende Literatur zu diesem Thema durch Einblicke in die Suchstrategien von 8.300 Unternehmen aus zwölf europäischen Ländern zu erweitern.

Auf der Basis von Tobit-Regressionsmodellen zeigen wir, dass die Faktoren, die die Breite und Tiefe einer Suchstrategie determinieren, deutlich variieren. Es wird deutlich, dass interne Forschung und Entwicklung eher zu einer tiefen als zu einer breiten Suchstrategie führt, während externe Forschung und Entwicklung die Unternehmen mit dem Zugang zu einer größeren Vielfältigkeit externen Wissens versorgt, was in der Konsequenz eine größere Breite der Suchstrategie impliziert. Ein freigebiges Innovationssystem, das Wissensspillovers ermöglicht, scheint die Unternehmen für eine höhere Forschungsbreite zu befähigen. Unsere Ergebnisse haben Implikationen für das Management von Unternehmen, indem wir Empfehlungen zur Ausgestaltung der Forschungstiefe und –breite eines Unternehmens anbieten.

Managing Search Strategies for Open Innovation – The Role of Environmental Munificence as well as Internal and External R&D

Wolfgang Sofka [a,b] and Christoph Grimpe [a,c,d]

[a] ZEW – Centre for European Economic Research, Mannheim (Germany)
[b] University of Hamburg (Germany)
[c] Catholic University of Leuven (Belgium)
[d] University of Zurich (Switzerland)

Abstract

Firms compete increasingly in an open innovation environment. Search strategies for external knowledge become therefore crucial for firm success. Existing research differentiates between the breadth (diversity) and depth (intensity) with which firms pursue external knowledge source. A consensus exists that resource constrains force firms to balance both dimensions. However, relatively little is known on how managers can selectively strengthen one of these dimensions. We argue conceptually that the breadth and depth of a search strategy depends upon the nature of a firm's absorptive capacity (i.e. whether they are built through internal or external R&D activities) and the munificence of its innovation environment. We test these hypotheses empirically for a large sample of more than 8,300 firms from 12 European countries. Our empirical results show that in-house R&D strengthens the depth of a firm's search strategy while external R&D activities (e.g. contract research) increase its breadth. Moreover, we find that scarce innovation environments favor deep search strategies while breadth is more prevalent in munificent environments. We develop targeted management recommendations based on these results.

Keywords: Open innovation, absorptive capacity, search strategies

JEL-Classification: L60, O32

E-mail correspondence: sofka@zew.de, grimpe@zew.de

This paper has been produced as part of the SYSTEMATIC Innovation Watch project within the Europe Innova Initiative, sponsored by the European Commission. Financial support is gratefully acknowledged. The authors thank Christian Rammer for invaluable feedback and discussions.

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). In order to define an appropriate search strategy, however, firms need to have developed the ability to recognize the potential value of external knowledge sources. In other words, the *absorptive capacity* of firms has a crucial role to play (Cohen and Levinthal, 1989, 1990).

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. Moreover, the search strategy should reflect the environment. Sirmon et al. (2007) have suggested that its effectiveness depends on environmental munificence. The varying munificence of environments might critically affect the potential value of a firm's resources and capabilities. Moreover, munificent environments can support the growth of resources within firms by providing access to complementary, external resources (Baum and Wally, 2003).

As a consequence, the munificence of the environment as well as firm-level factors are likely to influence the choice of search strategies. Little is known, however, what factors lead to such a choice, and determine the breadth and depth of a firm's search strategy. Our research aims at extending existing literature by providing insights into the search strategies of more than 8,300 firms from twelve 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. Regarding the firm-level factors we distinguish internal from external R&D activities (e.g. licensing) that contribute to the creation of absorptive capacity and thus enable a particular search strategy. With respect to the environmental munificence we investigate the availability of knowledge spillovers that firms may benefit from in a national context.

Based on tobit regression models we show that the factors determining breadth and depth of search strategies vary considerably. It turns out that internal R&D favors deeper over broader search strategy while external R&D provides the firm with the access to a higher diversity of external knowledge which in turn implicates higher breadth. A munificent innovation system

allowing for knowledge spillovers turns out to enable firms to higher search breadth. Our findings have implications for management in that we provide recommendations on how to shape the search breadth and depth of a firm. Hence, 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. The third section outlines our theoretical reasoning leading to our hypotheses. The subsequent sections present our empirical methods and our results which are discussed in section 6. Section 7 ends with concluding remarks and avenues for further research.

2 Theory review

2.1 External knowledge sources and Open Innovation

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 for 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 (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 implied 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 necessary capital to compete; third, the emergence of new external options for previously shelved inventions; and finally, external suppliers with increasing capabilities. This 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).

2.2 Search strategies

More recent literature has referred to this targeted process of identifying promising external knowledge in a firm's environment as its 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 deep 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 the two dimensions search scope and search depth. Here, 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 on 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.

Hence, there is a need for management implications on how firms can optimize their search strategies. As Laursen and Salter (2006) and Katila and Ahuja (2002) have shown it is not sufficient to simply extend both the breadth and depth of a search strategy. However, relatively little is known on how managers can strategically strengthen individual dimensions of their firms' search strategy, i.e. how to improve breadth instead of depth or vice versa. Our goal is to extend this stream of research by disentangling the processes behind building breadth and depth of search strategies. We argue that this depends upon the nature of their investments into absorptive capacity and the opportunities and challenges in the firm environment.

3 Hypothesis development

3.1 Absorptive capacity

External knowledge must be identified, activated and managed by an innovating firm in order to contribute to success (Gottfredson et al., 2005; Stock and Tatikonda, 2004). A firm's capability to exploit external knowledge has probably been captured best by Cohen and Levinthal (1989, 1990) concept of absorptive capacity. Absorptive capacity is defined as an innovator's ability to identify valuable knowledge within the environment, to integrate external sources with a firm's existing knowledge stock and to manage the exploitation phase for successful innovation. 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). Investments into absorptive capacities are therefore the basis for forming a firm's search strategy.

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). However, building these capabilities typically requires substantial time and resource commitments which limits 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 their ability to pursue alternative technological routes (see for example Levinthal and March, 1993). Hence, we suggest that firms building absorptive capacities through internal R&D investments require long-term commitments which should favor the strengthening of existing links with external knowledge sources and subsequently deeper search strategies. We hypothesize:

Hypothesis 1: Internal R&D investments lead to deep search strategies rather than of broad ones.

Internal R&D investment is only one possibility for building absorptive capacities. Dyer and Singh (1998) argue that absorptive capacities can also stem from engaging in interactions and collaborations with external partners. A certain level of technological expertise is required to engage in meaningful interaction, experience in initiating and managing knowledge exchanges with external partners may be of equal importance. Sofka (2008) differentiates

these effects when focusing on firms' technological versus international experience for internationalizing absorptive capacities. We argue that managers can strengthen their firm's breadth of search strategies by limiting internal resource commitments either through contracting R&D out to external partners or through the acquisition of other externally available knowledge like patents or licenses. In fact, technological change as well as the geographic and organizational dispersion of expertise have led to a wide variety of organizational arrangements for the generation and acquisition of knowledge (Teece, 1986, 1992). Traditionally, outsourcing, i.e. contracting out certain firm activities, had been largely used for rather specialized or repetitive tasks like logistics or facility management. Over time also other value chain activities closely related to the core of the firm – like production – have become subject to outsourcing decisions (Leiblein et al., 2002; Leiblein and Miller, 2003). Outsourcing of R&D activities basically follows the same logic in that it is directed at exploiting certain advantages associated with the nature and purpose of contract research organizations, whether they may be private firms or universities and research centers. These organizations provide the outsourcing firm with the opportunity to acquire rather disembodied knowledge which is considerably easier to transfer as it is largely codified and hence does not require the transfer of tacit knowledge. In other words, internal and external R&D can be seen as complements (Cassiman and Veugelers, 2006). As a result, external R&D may provide the firm with a more flexible approach to potential opportunities from a broad set of technological options and actors within an innovation system. Then again, it may limit a firm's opportunities to benefit in-depth from tacit or non-codified knowledge generated during the external R&D activities. In conclusion, we propose:

Hypothesis 2: External R&D investments lead to broad search strategies rather than of deep ones.

3.2 Munificence of the environment

Search activities can be affected by the availability of technological opportunities and the turbulence of the environment among other factors (e.g., Cohen and Levinthal, 1990). A firm's search strategy should reflect its environment and particularly its munificence in order to yield a favorable combination of linkages among users, suppliers and other important actors of the innovation system. Environmental munificence reflects the availability of opportunities for corporate venturing and renewal in an industry (Aldrich, 1979). Being conceptualized as a multidimensional concept, environmental munificence makes reference to the dynamism and abundance of technological opportunities, growth of the industry, and the demand for new products in a particular environment (Zahra, 1993; Zahra and Covin, 1995).

Environmental dynamism as a major element of its munificence describes the rate of change resulting from the market environment (Miller and Friesen, 1982, 1983). It centres around three major driving forces: competitors, customers and technology. Dynamism increases to the extent that these three forces provide stimuli for change. A rapid change of the dominant technology paradigm, for example, paired with the emergence of new competitors entering the marketplace as well as shifting customer demands will obviously cause a high level of environmental dynamism. The resulting pressure will affect potential value creation (Sirmon

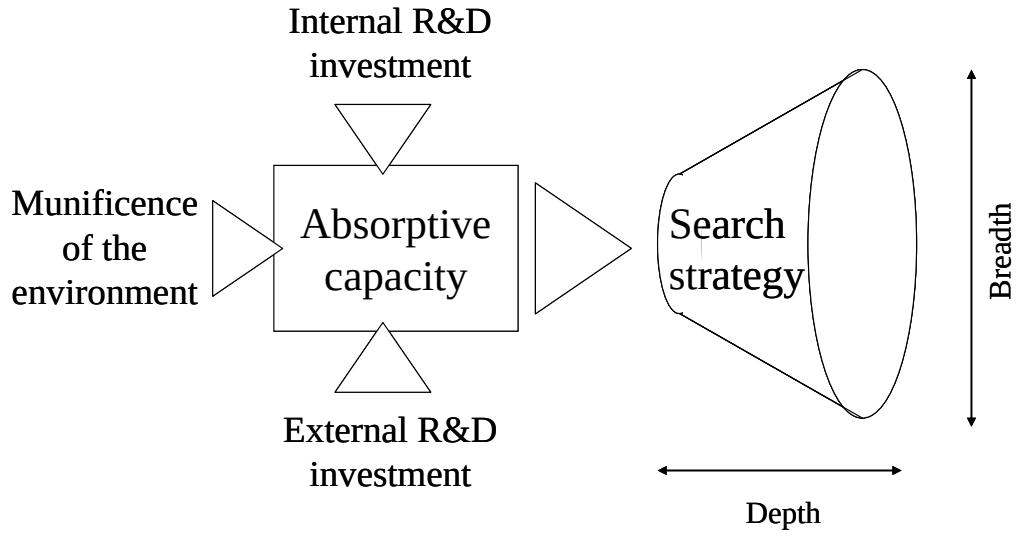
et al., 2007). But this pressure also forces firms to learn and develop routines to deal with environmental dynamism. The higher the rate of change the more the routines to cope with it get rewarded. Firms unable to do so will ultimately disappear. Hence, this pressure can also be a learning opportunity.

As a consequence, the varying munificence of environments might critically affect the potential value of a firm's resources and capabilities. Moreover, munificent environments can support the growth of resources within firms by providing access to complementary, external knowledge (Baum and Wally, 2003). Thus, the dimensions of a firm's search strategy may be altered by the characteristics of the knowledge environment (Grimpe and Sofka, 2008; Van den Bosch et al., 1999). As the availability of external knowledge sourcing opportunities increases we argue that it will be the search breadth which benefits from a higher munificence of the environment. In this sense, higher munificence will presumably relieve firms from the burden to be dependent on one or a few dominant external knowledge sources with which a higher search depth would be associated. Hence, our third hypothesis reads:

Hypothesis 3: Higher environmental munificence leads to broad search strategies rather than of deep ones.

Figure 1 summarizes our theoretical reasoning: Absorptive capacity is influenced by both internal and external R&D investments as well as by the munificence of the environment. All three influencing factors serve as determinants of the search strategy that can be characterized as a funnel along the dimensions of breadth and depth.

Figure 1: Conceptual model



4 Empirical strategy

4.1 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 the three-year period from 1998 to 2000. Heads of R&D departments or innovation management are asked directly if and how they are able to generate innovations. CIS data represent a substantial source of information, since the CIS offers representative firm data for all EU-27 member states. Therefore, the 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, 2008).

Although CIS-3 was performed in each EU member state, country data availability is restricted. For this analysis data are available for 12 European countries. Table 1 shows the composition of the sample.

Table 1: Number of observations per country

Country	Number of observations
Belgium	604
Czech Republic	1,161
Estonia	683
Germany	1,456
Greece	319
Hungary	128
Island	36
Latvia	14
Lithuania	535
Portugal	485
Slovak Republic	41
Spain	2,880
Total	8,342

CIS has a number of features to deal with 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).

4.2 Measures

Capturing 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 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 (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 eight different sources: the own company, suppliers, customers, competitors, universities, research institutes, professional conferences (including meetings and journals) as well as trade fairs. We construct two index variables to measure the breadth and the depth of search. Search breadth of firm *i* is defined as the number *n* of external sources for information *x* that were used by the firm, divided by the maximum of external sources used by firms in the sample:

$$breadth_i = \frac{\sum_{1}^{n} x_n}{\max(n)} \qquad (1)$$

Search depth of firm *i* is defined as the number *n* of external sources for information *z* which were highly important for the firm, normalized by the breadth of firm *i*:

$$depth_i = \frac{\sum_{1}^{n} z_n}{breadth_i} \qquad (2)$$

Measuring absorptive capacity

Absorptive capacities are not a tangible construct. Managers cannot simply be surveyed to judge their existence or extent. They are typically assumed to be a by-product of performing R&D activities. In line with the literature (Cohen and Levinthal, 1989; Rothwell and Dodgson, 1991) we capture absorptive capacities through the major input for innovation activities that is expenditure for R&D as a share of sales. In this respect, we have argued that in-house R&D activities are complemented by external R&D, i.e. the outsourcing of R&D to contract research organizations or the external acquisition of technology through patents or licenses. Both variables, expenditure for internal and external R&D, are therefore used and measured as a share of sales.

Measuring environmental munificence

We outlined the multidimensional nature of environmental munificence, encompassing the dynamism, the abundance of technological opportunities, growth of the industry, and the demand for new products in a particular environment (Zahra, 1993; Zahra and Covin, 1995). In the context of search strategies for externally available knowledge, however, we will concentrate the discussion on the munificence of the innovation environment in a region. Hence, we measure munificence as the gross domestic expenditure for R&D (GERD) for the twelve European countries under study. The source for these data is the OECD's statistics on Main Science and Technology Indicators (MSTI). 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. First, in order to control for other innovation related attributes of the firm we include a dummy variable indicating whether internal R&D activities were performed continuously. To capture the available human capital we include the ratio of employees with college education over sales. Moreover, firms may suffer from a liability of size or smallness. We capture these factors by including a firm's turnover 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, we include a dummy variable indicating whether a firm is located in a transition economy, i.e. a new European Union member state from Eastern Europe that has been going through the transition process to a market economy since the fall of the Soviet empire in 1990. Finally, we include industry dummies in terms of industry groups as defined in the classification of the OECD (2006).

4.3 Estimation method

We use a tobit model to estimate the determinants of search breadth and depth. This estimation method reflects the characteristics of our dependent variables which have been constructed as index variables with a minimum of 0 and a maximum of 1. Tobit models adequately account for such censored data.

5 Results

Table 2 shows the descriptive statistics. Out of the total sample of 11,656 observations only 8,342 could be used due to missing values in the variables used for analysis. It turns out, that firms on average have higher search breadth than depth. This might give an indication for the notion that search breadth may be easier to realize than search depth. Regarding our focus variables we find that firms spend 1.8 percent of their sales on average for internal R&D and 0.1 percent on external R&D. Moreover, the average spending of a country for R&D equals 1.3 percent.

Table 2: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Breadth	8342	0.656	0.264	0.125	1
Depth	8342	0.309	0.284	0	1
Share of internal R&D exp. of sales (ratio)	8342	0.018	0.070	0	0.997
Share of external R&D exp. of sales (ratio)	8342	0.001	0.005	0	0.049
Country R&D exp. as a percentage of GDP	8342	0.013	0.006	0.004	0.030
Cont. R&D activities (d)	8342	0.347	0.476	0	1
Empl. with college educ. over sales (ratio)	8342	0.005	0.013	0	0.191
Sales 1998 (log)	8342	15.517	2.016	6.908	23.990
Share of sales w/ exports (ratio)	8342	0.225	0.293	0	1
Transition economy (d)	8342	0.307	0.461	0	1
Other manufacturing (d)	8342	0.015	0.120	0	1
Low-technology manufacturing (d)	8342	0.290	0.450	0	1
Medium-technology manufacturing (d)	8342	0.354	0.478	0	1
High-technology manufacturing (d)	8342	0.046	0.210	0	1
Low knowledge-intensive services (d)	8342	0.141	0.348	0	1
Knowledge-intensive services (d)	8342	0.156	0.363	0	1

Variables are checked for multicollinearity. Table 4 in the appendix reports the variance inflation factors (VIF). From a mean VIF of 1.29 we can follow that multicollinearity does not present a challenge for our data (Belsley et al., 1980).

Table 3 shows the results of the estimations for separate tobit models on the breadth and depth of firms' search strategies. Three coefficients are of special importance as they test our theoretical hypotheses. They show significant results both on the firm-specific level of how firms' absorptive capacities influence the dimensions of their search strategies (hypotheses 1 and 2) as well as on the additional effects at the country level (hypothesis 3).

We find support for the positive effects of a firm's investment in internal R&D activities and the dimensions of its search strategies. Firms building absorptive capacities through internal R&D have both broader and deeper search strategies. However, the effect on depth is stronger than the effect on breadth. Hypothesis 1 is therefore supported. Apparently, management decisions to commit internal resources to laboratories and specialized personnel enable firms to establish in-depth knowledge exchange with particular knowledge sources.

This finding is in stark contrast to the effects of firm investment in external R&D. We find that external R&D leads to broader search strategies but has no significant effect on depth as predicted by hypothesis 2. Hence, contracting out R&D or acquiring external knowledge provides firms with the flexibility to pursue multiple options. This enhanced flexibility comes at the price of a lack of depth as external R&D may not provide access to knowledge which is not codified or tacit in nature.

We suggest in hypothesis 3 that the munificence of a firm's innovation environment has an additional effect on its search strategies. As predicted, we find that in countries with more munificent innovation environments, measured through the national R&D intensity, firms have significantly broader search strategies whereas less munificent environments favor depth. In that sense, search strategies do not only depend upon firm's absorptive capacities but also on opportunities or paucities in their environment. In environments with limited opportunities for knowledge sourcing managers opt to pursue deep search strategies extracting a maximum amount of knowledge from the relatively few available sources. In munificent environments, though, broader search strategies appear to be more appropriate as the risks from missing important technological or market opportunities increase.

Table 3: Marginal effects of tobit estimations

	Breadth	Depth
Focus variables		
Share of internal R&D exp. of sales (ratio)	0.24***	0.31***
	(0.06)	(0.07)
Share of external R&D exp. of sales (ratio)	2.80***	0.69
	(0.79)	(0.96)
Country R&D exp. as a percentage of GDP	0.04***	-0.02***
	(0.01)	(0.01)
Control variables		
Cont. R&D activities (d)	0.14***	0.09***
	(0.01)	(0.01)
Empl. with college educ. divided by sales (ratio)	0.23	-1.85***
	(0.30)	(0.41)
Sales 1998 (log)	0.03***	0.00*
	(0.00)	(0.00)
Share of sales w/ exports (ratio)	0.03**	-0.02
	(0.01)	(0.02)
Transition economy (d)	0.05***	-0.03***
	(0.01)	(0.01)
High-technology manufacturing (d)	0.06***	0.01
	(0.02)	(0.02)
Medium-technology manufacturing (d)	0.02**	-0.02*
	(0.01)	(0.01)
Other manufacturing (d)	0.00	-0.12***
	(0.03)	(0.04)
Knowledge-intensive services (d)	0.01	0.02
	(0.01)	(0.02)
Low-knowledge intensive services (d)	-0.03***	-0.01
	(0.01)	(0.02)
Constant (c)	0.12***	0.20***
	(0.03)	(0.04)
N	8342	8342
Log likelihood	-4006.40	-5608.82
LR/Wald chi2	985.16	201.82
p-value	0.00	0.00
Aldrich-Nelson R2	0.20	0.04

Standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.01
(d): Dummy variable
(c): Coefficient instead of marginal effect.

We do not develop specific ex-ante hypotheses on the control variables of the empirical model. However, significant results should be highlighted briefly. Continuous R&D activities, often times associated with having a dedicated R&D department, lead both to broader and deeper search strategies. Similarly, firm size (sales in 1998) has positive effects on both breadth and depth. We suspect that these effects capture the availability and commitment of resources to innovation activities within a firm. Interestingly, formal education of employees measured as the ratio of employees with college education is negatively related to the depth of a firms search strategy. We suggest that forming in-depth relationships with certain knowledge sources requires specific expertise often times acquired in mutual exchange over time instead of formal skills stemming from university education.

We find some significant results from the country and industry control variables. The coefficient of the dummy variable on whether a firm is located in a transition economy has the

same direction of effects on search strategy breadth and depth as the variable on country R&D intensity. We suspect that the dynamic evolvement of institutions in these countries reinforces the effects from the munificence of a firm's innovation environment. The significant industry effects may reflect technological dynamics and opportunities in certain sectors. More dynamic industries in medium- or high-tech manufacturing reward breadth in firms' search strategies indicating that the risks from missing important trends may be too high. In more technological stable sectors such as low-tech manufacturing and low-knowledge intensive services the necessity for engaging in knowledge exchanges with external partners may be more limited which is reflected in negative effects on their search strategies.

6 Discussion and conclusion

We conduct this analysis to provide new insights into how managers can optimize their search strategies for external knowledge. Our primary goal is to explore how firms can influence the specific dimensions of their search strategies, i.e. breadth and depth, as multiple studies have shown that tradeoffs between them exist (Grimpe and Sofka, 2008; Katila and Ahuja, 2002; Laursen and Salter, 2006). We argue that the breadth and depth of a firm's search strategy depend upon the nature of their absorptive capacities and the munificence of their environment.

Previous research has largely considered absorptive capacities as a by-product of internal R&D investments (e.g. Cohen and Levinthal, 1989, 1990). In line with this stream of literature we find that absorptive capacities built through internal R&D increase both the breadth and depth of a firms search strategy. However, we also find that the effect on depth is stronger. Committing internal resources to in-house labs and specialized scientists and engineers is therefore the primary path for innovation managers to achieve more depth in their search strategies. However, breadth can also be achieved through external R&D investment, e.g. contract research or other ways of acquiring external knowledge. The linkage between external R&D, related absorptive capacities and the breadth of a search strategy extends the research of Dyer and Singh (1998) on absorptive capacities built through interactive experience. Besides, we find that managers tailor their firm's search strategies to the challenges and opportunities of their environment. Our cross-country dataset enables us to draw distinctions between countries. In environments with limited opportunities for knowledge sourcing they opt to concentrate their efforts on deeply connecting with the few available ones, while a munificent environment leads to broad search strategies which may reflect the risks from missing important technological or market opportunities.

Our findings suggest a certain degree of sequencing of how managers can optimize their firms search strategies although we cannot explicitly test this empirically. Managers may opt to engage in external R&D when entering new technological fields or markets. This provides them with the necessary breadth in their search strategy to achieve a comprehensive overview of available opportunities. While external R&D provides flexibility, it remains superficial. The most promising elements of this broad search strategy need to be refined and extended.

Channels need to be established through prolonged interactions which foster a shared understanding and facilitate the exchange of valuable knowledge which is often times not codified but instead tacit (Laursen and Salter, 2006). This "deepening" of a firm's search strategy can be achieved through internal R&D investments which may result in hiring specialized personnel, developing skill sets or physical investments in laboratories. At this point the advantages of specialization outweigh the loss of flexibility. However, this mechanism is not independent from the national innovation environment of a company which influences the opportunities for designing search strategies. Managers in munificent environments will opt for broader search strategies before deciding on which ones to commit to deeply whereas managers in scarcer environments may be forced to opt for depth much sooner because of a lack of viable alternatives.

7 Concluding remarks and further research

This research has addressed an important gap in the literature on how search strategies are shaped within the firm. We have shown that both internal and external factors determine the search breadth and depth and that managers can pursue different avenues to foster either a broader or deeper search strategy. 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.

Finally, although we control for industry differences in our estimation it might well be that certain industries exhibit a very special search behaviour that is largely determined through idiosyncratic factors underlying the business logic of an industry. Hence, it would be interesting to study some industries more in depth, for instance the creative industries which have received considerable attention in the recent literature as they have been identified as a key growth engine for future competitiveness (e.g., Florida, 2002). This would also allow for much more fine-grained implications for management.

References

Aldrich, H.E. (1979), *Organizations and Environments*, Englewood Cliffs.

Amara, N. and R.j. Landry (2005), Sources of Information as Determinants of Novelty of Innovation in Manufacturing Firms: Evidence from the 1999 Statistics Canada Innovation Survey, *Technovation* 25 (3), 245-259.

Banbury, C.M. and W. Mitchell (1995), The Effect of Introducing Important Incremental Innovations on Market Share and Business Survival, *Strategic Management Journal* 16, 161-182.

Barney, J.B. (1991), Firm Resources and Sustained Competitive Advantage, *Journal of Management* 17 (1), 99-120.

Baum, J.R. and S. Wally (2003), Strategic Decision Speed and Firm Performance, *Strategic Management Journal* 24, 1107-1129.

Belsley, D.A., E. Kuh and R.E. Welsh (1980), *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity*, New York.

Bertrand, M. and S. Mullainathan (2001), Do People Mean What They Say? Implications for Subjective Survey Data, *American Economic Review* 91 (2), 67-72.

Bloom, N. and J. Van Reenen (2002), Patents, Real Options and Firm Performance, *Economic Journal* 112 (478), C97-C116.

Bowman, E.H. and D. Hurry (1993), Strategy through the Option Lens: An Integrated View of Resource Investments and The, *Academy of Management Review* 18 (4), 760-782.

Brockhoff, K. (1999), Technological Progress and the Market Value of Firms, *International Journal of Management Reviews* 1 (4), 485-501.

Cassiman, B. and R. Veugelers (2006), In Search of Complementarity in the Innovation Strategy: Internal R&D and External Knowledge Acquisition, *Management Science* 52 (1), 68-82.

Chesbrough, H.W. (2003), *Open Innovation - the New Imperative for Creating and Profiting from Technology*, Boston, USA.

Cohen, W.M. and D.A. Levinthal (1989), Innovation and Learning: The Two Faces of R&D, *The Economic Journal* 99, 569-596.

Cohen, W.M. and D.A. Levinthal (1990), Absorptive Capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly* 35 (1), 128-153.

Cohen, W.M. and D.A. Levinthal (1994), Fortune Favors the Prepared Firm, *Management Science* 40 (2), 227-251.

Conner, K.R. (1991), A Historical Comparison of Resource-Based Theory and Five Schools of Thought within Industrial Organization Economics. Do We Have a New Theory of the Firm?, *Journal of Management* 17 (1), 121-154.

Criscuolo, C., J.E. Haskel and M.J. Slaughter (2005), *Global Engagement and the Innovation Activities of Firms*, NBER Working Paper No. 11479, Cambridge, MA.

Dyer, J.H. and H. Singh (1998), The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage, *Academy of Management Review* 23 (4), 660-679.

Eurostat (2005), *Community Innovation Survey Light (Cis Light)*, http://europa.eu.int/estatref/info/sdds/de/inn/inn_cisl_sm.htm No., Luxemburg.

Florida, R. (2002), *The Rise of the Creative Class. And How It's Transforming Work, Leisure and Everyday Life*, New York.

Gallini, N.T. (2002), The Economics of Patents: Lessons from Recent U.S. Patent Reform, *Journal of Economic Perspectives* 16 (2), 131-154.

Galunic, C.D. and S. Rodan (1998), Resource Recombinations in the Firm: Knowledge Structures and the Potential for Schumpeterian, *Strategic Management Journal* 19 (12), 1193-1201.

Gemünden, H., M. Heydebreck and R. Wijnberg (1992), Technological Interweavement: A Means of Achieving Innovation Success, *R&D Management* 22 (4), 359-376.

Gottfredson, M., R. Puryear and S. Phillips (2005), Strategic Sourcing: From Periphery to the Core, *Harvard Business Review* 2005 (February), 132-139.

Gottschalk, S. and B. Peters (2008), *Evaluation of the Usefulness of Anonymised Cis Iii Data, Published by Eurostat, for Econometric Analyses*, ZEW Discussion Paper No. forthcoming, Mannheim.

Grant, R.M. (1996), Toward a Knowledge-Based Theory of the Firm, *Strategic Management Journal* 17, 109-122.

Griliches, Z. (1979), Issues in Assessing the Contribution of Research and Development to Productivity Growth, *Bell Journal of Economics* 10 (1), 92-116.

Grimpe, C. and W. Sofka (2008), Search Patterns and Absorptive Capacity: Low- and High-Technology Sectors in European Countries, *Research Policy* forthcoming.

Huston, L. and N. Sakkab (2006), Connect and Develop, *Harvard Business Review* 84 (3), 58-66.

Jaffe, A.B. (1986), Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Values, *American Economic Review* 76 (5), 984-1001.

Jensen, M.B., B. Johnson, E. Lorenz and B.A. Lundvall (2007), Forms of Knowledge and Modes of Innovation, *Research Policy* 36 (5), 680-693.

Kaiser, U. (2002), An Empirical Test of Models Explaining Research Expenditures and Research Cooperation: Evidence for the German Service Sector, *International Journal of Industrial Organization* 20 (6), 747-774.

Katila, R. (2002), New Product Search over Time: Past Ideas in Their Prime?, *Academy of Management Journal* 45 (5), 995-1010.

Katila, R. and G. Ahuja (2002), Something Old, Something New: A Longitudinal Study of Search Behavior and New Product Introduction, *Academy of Management Journal* 45 (6), 1183-1194.

Laursen, K. and A. Salter (2006), Open for Innovation: The Role of Openness in Explaining Innovation Performance among U.K. Manufacturing Firms, *Strategic Management Journal* 27 (2), 131-150.

Leiblein, M.J. and D. Miller, J. (2003), An Empirical Examination of Transaction and Firm-Level Influences on the Vertical Boundaries of the Firm, *Strategic Management Journal* 24, 839-859.

Leiblein, M.J., J.J. Reuer and F. Dalsace (2002), Do Make or Buy Decisions Matter? The Influence of Organizational Governance on Technological Performance, *Strategic Management Journal* 23 (9), 817-833.

Levinthal, D.A. and J.G. March (1993), The Myopia of Learning, *Strategic Management Journal* 14 (8), 95-112.

Liebeskind, J.P. (1996), Knowledge, Strategy, and the Theory of the Firm, *Strategic Management Journal* 17, 93-107.

March, J.G. (1991), Exploration and Exploitation in Organizational Learning, *Organization Science* 2 (1), 71-87.

Miller, D. and P.H. Friesen (1982), Innovation in Conservative and Entrepreneurial Firms: Two Models of Strategic Momentum, *Strategic Management Journal* 3 (1), 1-25.

Miller, D. and P.H. Friesen (1983), Strategy-Making and Environment: The Third Link, *Strategic Management Journal* 4, 221-235.

Nadiri, I.M. (1993), *Innovations and Technological Spillovers.*, NBER Working Paper No. 4423, Cambridge, MA.

Ndofor, H.A. and E. Levitas (2004), Signaling the Strategic Value of Knowledge, *Journal of Management* 30 (5), 685-702.

OECD (2006), *Science, Technology and Industry Outlook*, Paris.

Peteraf, M.A. (1993), The Cornerstones of Competitive Advantage: A Resource-Based View, *Strategic Management Journal* 14 (3), 179-191.

Porter Liebeskind, J. (1997), Keeping Organizational Secrets: Protective Institutional Mechanisms and Their Costs, *Industrial & Corporate Change* 6 (3), 623-663.

Rosenkopf, L. and A. Nerkar (2001), Beyond Local Search: Boundary-Spanning, Exploration, and Impact in the Optical Disc Industry, *Strategic Management Journal* 22 (4), 287-306.

Rothwell, R. and M. Dodgson (1991), External Linkages and Innovation in Small and Medium-Sized Enterprises, *R&D Management* 21, 125-137.

Sapienza, H.J., E. Autio, G. George and S.A. Zahra (2006), A Capabilities Perspective on the Effects of Early Internationalization on Firm Survival and Growth, *Academy of Management Review* 31 (4), 914-933.

Sirmon, D.G., M.A. Hitt and R.D. Ireland (2007), Managing Firm Resources in Dynamic Environments to Create Value: Looking inside the Black Box, *Academy of Management Review* 32 (1), 273-292.

Sofka, W. (2008), Globalizing Domestic Absorptive Capacity, *Management International Review* forthcoming.

Stock, G.N. and M.V. Tatikonda (2004), External Technology Integration in Product and Process Development, *International Journal of Operations & Production Management* 24 (7), 642-665.

Subramaniam, M. and M.A. Youndt (2005), The Influence of Intellectual Capital on the Types of Innovative Capabilities, *Academy of Management Journal* 48 (3), 450-463.

Szulanski, G. (1996), Exploring Internal Stickiness: Impediments to the Transfer of Best Practice within the Firm, *Strategic Management Journal* 17, 27-43.

Teece, D.J. (1986), Profiting from Technological Innovation. Implications for Integration, Collaboration, Licensing and Public Policy, *Research Policy* 15, 285-305.

Teece, D.J. (1992), Competition, Cooperation, and Innovation: Organizational Arrangements for Regimes of Rapid Technological Progress, *Journal of Economic Behavior and Organization* 18, 1-25.

Tsang, E.W.K. (2000), Transaction Cost and Resource-Based Explanations of Joint Ventures: A Comparison and Synthesis, *Organizational Studies* 21 (1), 215-242.

Van den Bosch, F.A.J., H.W. Volberda and M. de Boer (1999), Coevolution of Firm Absorptive Capacity and Knowledge Environment: Organizational Forms and Combinative Capabilities, *Organization Science* 10 (5), 551-568.

Wernerfelt, B. (1984), A Resource-Based View of the Firm, *Strategic Management Journal* 5 (2), 171-180.

Zahra, S.A. (1993), Environment, Corporate Entrepreneurship, and Financial Performance: A Taxonomic Approach, *Journal of Business Venturing* 8 (4), 319-340.

Zahra, S.A. and J.C. Covin (1995), Contextual Influences on the Corporate Entrepreneurship-Performance Relationship: A Longitudinal Analysis, *Journal of Business Venturing* 10 (1), 43-58.

Zahra, S.A. and G. George (2002), Absorptive Capacity: A Review, Reconceptualization, and Extension, *Academy of Management Review* 27 (2), 185-203.

Appendix

Table 4: Collinearity diagnostics

Variable	VIF
Share of internal R&D exp. of sales (ratio)	1.20
Share of external R&D exp. of sales (ratio)	1.06
Cont. R&D activities (d)	1.31
Empl. with college educ. over sales (ratio)	1.29
Sales 1998 (log)	1.40
Share of sales w/ exports (ratio)	1.23
Country R&D exp. as a percentage of GDP	1.26
Transition economy (d)	1.37
Other manufacturing (d)	1.06
Medium-technology manufacturing (d)	1.54
High-technology manufacturing (d)	1.16
Low knowledge-intensive services (d)	1.37
Knowledge-intensive services (d)	1.54
Mean VIF	1.29