

R&D, perception and innovation

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Abstract

Organizational search processes is a main source of firm level heterogeneity in evolutionary and behavioural theory. Drawing on this insight we argue that R&D and organizational perceptions are empirical manifestations of search behaviour that are related to the organizational capacity to innovate. Using a new survey of industrial enterprises we find that both types of search behaviour are related to product, process, organizational and market innovation at the firm level. Our main contribution is empirical as empirical research lags behind theoretical understandings of firm heterogeneity in relation to innovation in evolutionary economics.

1. Introduction

It is a “core” notion in evolutionary theory that firms pursue different learning activities, use different types of knowledge in the innovation process, and hence pursue different approaches to innovation (Nelson & Winter, 1982; Nelson, 1991; Nelson, 1995; Winter, 1984). Empirical analysis of these issues is lacking however. Recent theoretical advances in evolutionary economics have a loose empirical foundation (Fagerberg (2003). This is a shortcoming in a discipline where appreciative theorizing based upon empirical studies has been a defining feature (see Nelson & Winter, 1982; Nelson, 1995; Fagerberg, 2003; Fagerberg & Verspagen, 2002).

In this paper we explore the range of search channels firms use in the innovation process and whether different search channels are related to different innovation outcomes. Our objective is as such to analyse firm heterogeneity and relate this observed variety to different kinds of outcomes from the innovation process. In order to do so we focus on the learning activities (R&D) firms undertake in the innovation search process and the perceptions firms have in this regard. Both R&D and perceptions are in our theoretical framework empirical manifestations of organizational search processes for (different kinds of) innovations.

Research and development (R&D) play an important role in evolutionary accounts of firm heterogeneity and has frequently been used as a measure of search activity in theoretical research (Nelson, 1961; Nelson & Winter, 1982; March, 1991). This is because R&D is a measure of non-codified learning and tacit knowledge (Arora & Gambardella, 1990; Helfat, 1994). Non-codified learning and tacit knowledge are important sources of difference in performance and profitability across firms over time (Teece et al, 1997; Barney, 1991; Rumelt, 1991; Macpherson & Holt, 2007).

R&D lies as such at the heart of an evolutionary theory of business firm development, strategy and innovation (Helfat, 1994; Nelson, 1995; Winter, 1984). Prior empirical research has however been largely unable to analyze whether different kinds of R&D activities enhance the organizational capacity to innovate in a diverse way. In this paper we take a closer look at the role of internal – and external – R&D for the organizational ability to develop product, process, organizational and market innovations.

According to behavioural and evolutionary theories of the firm, organizations have heterogeneous perceptions (Cyert & March, 1963; Nelson & Winter, 1982)). Heterogeneous perceptions can constitute a source of inter-firm differences in search capabilities. Cognitions are to a substantial extent unique to firms. Prior empirical research has to a large extent neglected the role of organizational perceptions in the innovation process. Recent theoretical research has on the other hand stressed that organizational perceptions constitute an important source of organizational search activity that enables change at the firm level (Gavetti, 2005; Gavetti & Levinthal, 2004). In order to follow up this theoretical research in an empirical manner we will take a closer look at the whether perception of problems initiate search activity and enhance the organizational ability to innovate. In this paper we thus analyze the actual micro-linkages between perception of problems and search activity within the context of industrial innovation.

Drawing on evolutionary and behavioural theories of the firm we argue that organizational search based on R&D is close to deliberate problem solving efforts based on retained experience. Innovation searches based on perceptions draw in comparison less on retained knowledge in the search for new variety, technology and innovation. Although both types of search processes are important they might be related to different types of outcomes from the innovation process. Hence, heterogeneity in search activity among organisations can be related to a variety of outcomes from innovation search processes. Empirical analysis of this issue has lagged behind theoretical research in evolutionary economics – and is the main contribution from this paper to the literature.

The research in this paper benefits from a novel survey where detailed information about R&D spending, the problems firms perceive in the innovation process, and innovations developed, has been collected from a representative sample of firms from the Norwegian enterprise population. A detailed database is as such available to us where we can shed new empirical light on firm heterogeneity in the innovation process and relate this observed variety to different kinds of innovation outcomes (product, process, organizational and market innovations).

This paper is organized as follows: In the next section we will discuss theoretical research related to how and why firms are believed to differ in their approach to innovation. We will discuss features of our Norwegian case in section 3. The methodology, data and variables

used in the analysis are discussed in section 4. The empirical analysis is conducted in section 5, which is accompanied by a discussion of the empirical results. We draw some conclusions and implications for further research in section 6.

2. Search and innovation

Joseph Schumpeter was one of the first to provide an analysis of the importance of innovation for economic change. He devised a “model” where endogenous technological change is an outcome of investments made by business firms to compete and beat their rivals (Nelson, 1995). According to this view economic growth occurs through a process of creative destruction where the old industrial structure – its product, its process, or its organization – is continually changed by innovation (Link, 1980). This theoretical insight has influenced researchers to study the sources and impacts of innovation in the economy (see Fagerberg et al, 2005 for a survey).

Inspired by Schumpeter’s work, evolutionary theorists have increasingly highlighted qualitative differences between firms engaged in innovative activity as a major source of innovation and economic progress (Nelson, 1991; Nelson, 1995). The ability to develop and introduce new innovations - or “new combinations” as Schumpeter called it - in the economy is a major source of economic change in evolutionary theoretical frameworks (Fagerberg, 2005; Verspagen, 2005). Evolutionary theory is consistent with a large body of empirical work that has documented the existence of considerable and persistent intra-industry inter-firm differences in profitability and growth rates (Nelson, 1995). The overall evolutionary-theoretical story is thus one in which firms pursue different approaches to innovation, build unique capabilities, and hence develop different kinds of innovations.

Empirical analysis of these issues is lacking however. Contrary to what one might expect, empirical research lags behind theoretical research in evolutionary economics. Recent theoretical advances in evolutionary economics have a loose empirical foundation (Fagerberg (2003). This is an obvious shortcoming in a discipline where appreciative theorizing based upon empirical studies has been a defining feature (see Nelson & Winter, 1982; Nelson, 1995; Fagerberg, 2003; Fagerberg & Verspagen, 2002). A main aim in this paper is as such to provide an empirical connection back to evolutionary theory where processes associated with

the theoretical core evolutionary economics (e.g. firm heterogeneity) are analyzed empirically.

A key undertaking in this paper is as such to empirically explore the diverse ways in which firms search for new innovations and to analyze whether this observed variety is related to different outcomes from innovation search processes. In order to do so we will start by taking a closer look at the deliberate problem solving efforts firms undertake in the innovation process. We will in this context take a closer look at the organizational search routine (Nelson & Winter, 1982; Cyert & March, 1963) in the context of industrial R&D.

2.1 Deliberate search and industrial R&D

Nelson & Winter (1982) have proposed that organizational search routines and processes are a main driving force behind innovation at the firm level. Search processes are the deliberate problem-solving activities firms undertake within the context of industrial innovation (Nelson & Winter, 1982; Cyert & March, 1963). In this theoretical framework organizations learn by storing knowledge in routines that guide behaviour (Levitt & March, 1988). Although it is a clear notion in evolutionary economics that firms invest in search and learning, we know little about “what type” of learning organizations invest in, and how this is related to organizational capacity to innovate (Fagerberg, 2003). As argued above, there is a lack of empirical research on this subject matter.

Research on organizational routines is haunted by conceptual ambiguity as to how routines should be defined and interpreted in empirical research (Becker, 2005; Becker et al 2005; Becker, 2004). Although the empirical measurement of organizational routines is a “hard nut to crack”, it is a central issue in evolutionary studies of firm behaviour. In this paper we take a closer look at firms’ search routines and the learning activities undertaken to find solutions to technological problems, e.g., .the deliberate processes firms undertake in order to discover better ways of doing things (Nelson, 1995). How can these deliberate search processes be measured in empirical work?

We simply adopt Nelson’s (1995) own answer to basically the same question: “Winter and I have found it convenient to call such search R&D (p.69)”. This view is essentially a follow-up of an earlier paper by Nelson (1961) where he argues that R&D represents the institutionalization of inventive activities at the firm level. Hence, we will conduct an analysis

of firm level R&D activities in order to shed empirical light over the deliberate problem-solving activities firms execute in the innovation search process. We thus view R&D activity as an empirical manifestation of the organizational ability to execute deliberate learning and search activities for new technologies and knowledge (Nelson & Winter, 1982; Carroll & Hannan, 2000). This type of search activity tends to build on retained knowledge and expertise, as discussed below.

Firms tend to persist in the amount of efforts they devote to different kinds of R&D activities (Helfat, 1994). Persistence of R&D arises due to the path-dependant character of the innovation process where firms search for new technologies in the neighbourhood of current practice and competence (Nelson & Winter, 1982). Experience with a set of organizational routines will enhance the competence of the firm which will spark off a search process where a main aim is to refine existing technology and to exploit prior knowledge investments and innovations (Cyert & March, 1963; Nelson & Winter, 1982; Stuart & Podolny, 1996). Routines are as such history-dependant and based upon interpretation of the past (Levitt & March, 1988). Hence, evolutionary processes, such as organizational search behaviour based on R&D, are characterized by strong regularities or “persistence” (Fagerberg, 2003; Dosi, 1988).

Yet another key evolutionary notion is the theoretical idea that firms pursue different approaches to innovation and that they are able to change their knowledge base in relation to the perception of problems (Cyert & March, 1963; Nelson & Winter, 1982; Nelson, 1991; 1995; Dosi et al; 1997; Dosi & Marengo, 2007). Qualitative differences between firms are as such more than just differences in R&D efforts across firms. Although the notion of heterogeneous agents is a building block in evolutionary economics (Dosi & Marengo, 2007), one might ask how such differences emerge.

In order to provide an answer let us go back to Schumpeter’s (1934) treatment of the entrepreneur. The idea that the organizational capacity to innovate are unevenly distributed in the firm population is essentially Nelson & Winter’s (1982) interpretation of Schumpeter, where Schumpeter argued that some individuals will choose to become entrepreneurs due to differences in talents and psychological attributes (Fagerberg, 2003). Hence, an important source of firm heterogeneity is as such related to differences in “psychological attributes”

across firms, e.g. differences in how organizations think and perceive the world (Fagerberg, 2003).

Organizational cognitions and perceptions have only recently (re)emerged as an important subject matter in theoretical research. “Cognitions and perceptions” have in this regard been put forth as an explanation for how firms are able to “break away” from retained knowledge and technology in order to change their knowledge base and search behaviour (Gavetti, 2005; Gavetti & Levinthal, 2004). Organizational perceptions could as such constitute an independent source of heterogeneous search behaviour, apart from R&D. These search processes could as such constitute an important part of the organizational ability to develop new innovations. How perceptions are linked to search behaviour and innovation is discussed in more detail below.

2.2 Search based on perceptions

Firms have different cognitions and perceptions (Nelson & Winter, 1982; Nelson, 1991; Fagerberg, 2003). Differences in perception and cognition arise because firms are boundedly rational and lack perfect information (Cyert & March, 1963; Nelson & Winter, 1982; Fagerberg, 2003). The development of new technologies is as such an outcome of learning processes where firms search for new routines in a limited-rational way (Nelson, 1995; Kline & Rosenberg, 1986; Dosi et al 1997). Hence, how firms think and perceive the world matters (Fagerberg, 2003). Organizations do as such enact their own environment through how they perceive the world and initiate strategies and so on based upon these perceptions (Weick, 1979; Levinthal & March, 1993).

In the behavioural theory of the firm, organizations initiate search efforts when their performance falls below an aspiration level that is socially or historically constructed (Cyert & March, 1963; Greve, 2003). Some interesting empirical research has been conducted on this subject in relation to performance-feedback theory (Greve, 2003) that draws heavily on the behavioural theory of the firm (Cyert & March, 1963). A main conclusion from this research is that organizational search behaviour is initiated when organizational performance falls below a socially constructed aspiration level. This kind of search activity is positively related to R&D and innovation at the firm level (Greve, 2003). We do as such see that *perception* of performance is a key issue in relation to organizational search in behavioural theory. Research on performance feedback theory has on the other hand mainly used objective

financial measures in order to construct proxies for performance relative to an aspiration level. How the perception of other problems impact on search activity in this regard has not been analyzed empirically using large scale databases.

A recent in-depth qualitative study suggests on the other hand that firms respond in a proactive way to most of the problems they encounter. In the study it was concluded that “Spurred by the problems they encounter, entrepreneurial firms revise their business conjectures and engage in innovative activities” (Hugo & Garnsey, 2004). Qualitative research findings do as such also suggest that problems initiate search. In this paper we will take a large scale quantitative approach to the same issue.

What the above discussions clearly suggest is that perception of problems is linked to search behaviour. Perception of possible problems is in this context a key aspect of managerial and firm performance insofar as learning is initiated to overcome challenges (Levitt & March, 1988). Perception of problems can as such trigger action, learning and search activity. Because organizations change in response to perceived problems (Amburgey et al, 1993), perception of problems can be related to innovation.

Although firm and managerial cognitions can differ along a wide array of dimensions, we are in this paper primarily interested in differences in cognitions as they relate to innovation and the search for new technology and knowledge. In this context we are especially interested in the perceived problems firms face in the innovation process. We are not aware of prior research where the empirical links between the perception of problems and challenges in the innovation process on the one hand, and the types of innovations firms develop on the other hand, have been analyzed empirically using large scale databases.

The relationship between perception of problems in the innovation process and subsequent innovative efforts is put forth as a key issue by seminal theoretical contributions within innovation studies however. According to Kline & Rosenberg (1986), the perception of rising development costs, large financial risks, technological uncertainty, regulatory constraints and lack of markets, poses serious threats to the organizational capacity and willingness to initiate innovation processes and to innovate. To what extent can these “concerns” be observed empirically?

Although the Kline & Rosenberg (1986) model has been highly influential, their concerns should be tested empirically. Are organizational search processes influenced in a negative way by Kline & Rosenberg's (1986) concerns? Or is a more "open" approach relevant where "cognitions" and perception of problems also can generate new questions and searches for new knowledge in order to overcome challenges, as proposed but not analyzed in a recent review (Malerba, 2005) and by qualitative research on this subject matter (Hugo & Garnsey, 2004)?

At a deeper theoretical level our discussion of firms "cognitive abilities" overlaps with the sources of firm heterogeneity and the characteristics of organizational learning processes (Dosi et al, 1997; Dosi & Marengo, 2007). These theoretical conjectures are rather broad however. Although the theoretical idea that perception of problems will trigger action and search activity at the firm level is well established, we know little about the actual impact different types of perceptions have in this regard. In addition, there is hardly any empirical research on this subject matter.

Due to the absence of precise theoretical analysis and lack of empirical research on this issue we have chosen to take an explorative approach to the subject matter. We have not developed concrete expectations or hypothesis to be tested, apart from the overall theoretical idea that perception of problems is related to search activity and (different types of) innovative activity. A central part of this paper is as such to conduct an empirical analysis of the rather simple argument in evolutionary and behavioural theory that perceptions of problems initiate search for new technology, knowledge and innovation. We will in this regard explore how a range of different organizational perceptions influence innovative activity at the firm level.

2.3 Summing up

We have in this paper argued that organizational search processes is a main source of firm level heterogeneity in evolutionary and behavioural theory. Organizational search can be based on retained knowledge and experience. R&D is an empirical manifestation of such search activity, and can be split into sub-categories such as internal and external R&D. Search activity can on the other hand also be triggered by organizational perceptions and cognitions. Such search activity relies far less on deliberate problem solving based on retained knowledge. Perceptions and cognitions can also be split into different sub-categories.

Hence, there exist a range of search channels that firms can follow in the innovation process. How these search activities are related to the organisational capacity to develop different types of innovations is a rather unexplored empirical terrain. As argued by others, it is important to shed light over such issues in order to advance the evolutionary- theoretical understanding of firm behaviour (Fagerberg, 2003). Below we will discuss in more detail how concrete organizational perceptions might be related to innovation with reference to some descriptive statistics.

3. Exploring search activities: descriptive statistics

We argued in the above section that both R&D and the perception of problems are empirical manifestations of search activity. In order to shed some empirical light over these issues, we will in this section briefly present some descriptive statistics on the hampering factors firms perceive to be important in the innovation process, the use of R&D, and the different types of innovations firms have developed. The statistics presented in this section refer to the 2002-2004 time period and are broadly representative for the enterprise population in Norway with 10 or more employees. The survey data are discussed in more detail below, in section 4.

Let us start with R&D. In table 1 below we have explored the extent to which Norwegian firms are engaged in R&D. We do so for both internal R&D and external R&D. As we can see in table 1, about 33 % of the firms in our sample claimed to have been engaged in internal R&D in the time period 2002-2004. Almost 21 % of the firm claimed to have been engaged in external R&D in the same time period. Hence, internal R&D is the preferred search activity when Norwegian firms search for new technology and knowledge.

Table 1. Engagement in internal and external R&D

	% yes	N
Internal R&D	32,9	4655
External R&D	20,9	4655

Data source: Own calculation based upon the Norwegian CIS 4 survey.

In the above section we argued that internal and external R&D constitute separate search pathways to innovation. Table 2 sheds some light over this issue. As we can see in the table, some firms only use internal R&D in the search process, while some firms only use external R&D in the search for new innovations. But the share of firms using only external R&D is low. Firms using external R&D also tend to engage in internal R&D. This is in line with the

literature on absorptive capacity (Cohen & Levinthal, 1989; 1990) where it is more or less argued that internal R&D is a prerequisite for being able to draw on external knowledge in the innovation process.

Table 2. Overlap between internal and external R&D

	% yes
Only internal R&D	14,3
Only external R&D	2,3
Both internal and external R&D	18,6
No R&D activity	64,8
N	4655

A central argument in this paper is that organizational perceptions are an important source of firm heterogeneity in relation to innovation at the firm level. Table 3 sheds some empirical light over this. In table 3 below we have provided the percentage share of firm managers in our survey who perceive the displayed factors to be “important” as an obstacle to innovation. The scale goes from 0 = not relevant, to 3 = high importance. Because some managers did not answer the questions about innovation obstacles in the survey we lack answers from around 300 firms.

Table 3. Percentage of firms answering “not relevant to high importance” on innovation obstacles

Innovation obstacle	Not relevant	Little Imp.	Medium Imp.	High Imp.	Sum	N
Innovation costs too high	50,6	16,6	21,9	10,9	100 %	4339
Lack of finance within the enterprise	52,9	21,4	16,4	9,2	100 %	4310
Lack of finance from outside the enterprise	58	20	13,5	7,7	100 %	4303
Lack of qualified personnel	55	27,7	13,6	3,7	100 %	4323
Lack of information on technology	54,9	32,6	10,5	2	100 %	4325
Lack of information on markets	54,6	30,2	12,9	2,3	100 %	4326
Lack of cooperation partners for innovation	59,7	27,9	10,3	2,1	100 %	4305
Market dominated by established incumbents	57,7	23,8	13,5	4,9	100 %	4300
Uncertain demand after new goods and services	52,8	21,2	19,5	6,5	100 %	4312

Data source: Own calculation based upon the Norwegian CIS 4 survey.

We discussed previously that perceived barriers to innovation can constitute an important source of search activity. Perception of “deep” problems can in such a theoretical framework trigger organizational search responses (Cyert & March, 1963; Nelson & Winter, 1982). In table 3 we can see that the most “highly cited” innovation obstacles are “innovation costs” and “lack of finance”. “Lack of finance” and “high innovation costs” are usually put forth as negative determinants of innovation in the literature (Hall, 2002; Kline & Rosenberg, 1986). It remains to see whether the perceptions of such obstacles are related in a different way to innovation. Could it be the case that detection of possible “cost” and “financing” issues

trigger search for solutions to overcome such problems? This is an issue we will return to in section 5.

It is also interesting to note that “uncertain demand” and “market domination by established incumbents” are perceived as among the most important barriers to innovation by the responding firm managers in our survey. Understanding the role of demand in innovation processes has been highlighted as important in recent reviews of the literature (Castellacci et al, 2005; Pianta, 2005), as well as understanding the role of innovation in relation to industry entry barriers (Geroski, 1995; Audretsch, 2001). Will firms with such perception try to innovate in order to create new demand or innovate in order to destroy the existing industrial structure and market domination by established incumbents? We will touch upon these issues in section 5 where we will analyze whether firms with such perceptions are more or less inclined to innovate.

According to the firm managers in our surveyed firms it is not difficult to find an “innovation cooperation partner” or, in other words, lack of such a partner does at least not constitute a barrier to innovation for the overall majority of firms. How does such a perception impact on firm level innovation processes? Access to innovation networks is generally believed to be an important determinant of innovation (Powell & Grodal, 2005). Will firms who find it hard to identify an innovation cooperation partner be less inclined to innovate?

It is also interesting to note that “lack of technological information” and “lack of market knowledge” are not highly cited as important barriers to innovation. Do firms that perceive these factors to be of low importance innovate more frequently, as suggested by for instance Kline & Rosenberg (1986)? If so, the Norwegian enterprise population should be highly innovative. Or is it on the other hand more likely that innovative firms simply perceive more problems (Baldwin & Lin, 2002; Galia & Legros, 2004; Mohnen & Röller, 2005)? If so, the level of innovation should be rather low in Norway. We shed some empirical light over this in table 4 below.

In table 4 we have analyzed the prevalence of product, process, organizational and market innovation in the Norwegian enterprise sector. According to the statistics in table 3, almost 30 % of the firms in our sample developed a product innovation, while about 24 % developed a process innovation in the time period 2002-2004. Product and process innovation have been

the usual indicators of innovative activity in the literature. It is therefore interesting to explore the prevalence of market and organizational innovation in the enterprise population. According to table 3, about 28 % of the firms had undertaken an organizational innovation, while almost 26 % of the firms had developed a market innovation in the same time period. Organizational and market innovations are as such equally prevalent among firms in the Norwegian enterprise population as product and process innovation.

Table 4. Percent of firms having developed an innovation, distributed by innovation types

Type of innovation	% yes	N
Product innovation	29,7	4655
Process innovation	23,6	4655
Organizational innovation	27,6	4655
Market innovation	25,5	4655

Data source: Own calculation based upon the Norwegian CIS 4 survey.

4. Method, data and variables

In this section we will discuss the methodology, data and variables used in the analysis. The main aim is to analyze how R&D and perceptions are related to innovation at the firm level. Binary innovation indicators will be used in the analysis as dependant variables. Therefore we will estimate the relationship between R&D, perceptions and innovation using logistic regression analysis. Logistic regression has been especially designed to handle binary dependant variables where the presence or absence of an outcome is analyzed (innovation or not innovation).

4.1 Data

The research in this paper builds upon a novel R&D and innovation survey that was distributed to a representative sample of Norwegian enterprises with 10 employees or more in 2006. The majority of questions refer to the time period 2002-2004, but some also refer to 2004. Every firm with 50 or more employees was included in the sampling frame. The survey is the Norwegian implementation of the fourth Community Innovation Survey (CIS).

In this paper we do as such use survey data where managers are asked a range of questions about R&D activity, innovation, and the problems firms perceive in the innovation process. One methodological problem with these kinds of survey data is subjectivity (Smith, 2005). Subjectivity can create some problems, most notably for survey questions that are supposed to be “objective”, like R&D and innovation. In the end it is up to the respondent to decide

whether a product is a new innovation, and whether some activity falls under the R&D rubric. R&D and innovation are important firm level activities. In our view managers should be capable of providing answers to simple questions about R&D and innovation without too much error. Firm managers are usually highly educated people.

The methodological approach we follow in this paper was first initiated by Mansfield (Scherer, 2005). The main point with this approach is simply that:” if you want to know something, ask the people who know” (Scherer, 2005, p 5). Subjectivity can in this regard also be an advantage, most notably for evolutionary oriented scholars who argue that firms have different cognitions and perceptions. The survey data we have access to ask managers about whether they perceive different innovation obstacles to be a problem in the innovation process. In this particular case, it is subjectivity that we want.

It is important to stress that every firm in the sample frame was asked to answer the questions about R&D activity, also non-innovative firms. This is a special feature of the Norwegian implementation of the CIS survey. All the questions used in the analysis have as such been posed to both innovators and non-innovators. The survey was returned by 4655 firms which constitutes a response rate of 93 %. The high response rate needs to be seen in relation to the fact that it was compulsory for firms to return the questionnaire. It can always be argued that the compulsory nature of the R&D survey can lead to bad data quality. We do not think this is the case in our Norwegian context. R&D surveys have been conducted since the 1970’s by Statistics Norway. Statistics Norway is considered to be an impartial and well recognized institution in Norway. Further, Statistics Norway has undertaken a lot of efforts to ensure that the data quality is good, efforts which can not be matched by single researchers or consultancy firms. For instance, firms with missing values on the R&D variables were contacted and asked to provide the necessary information.

Due to some missing values on the independent variables used in the analysis, most notable in association with the “perception variables”, the sample size drops with around 400 firms. There are no missing values on our R&D or innovation variables however. In total, the problem with item non-response and missing observations represents around 10 % of the total sample. This should not constitute a major source of selection bias.

4.2 Variables

We have 4 dependant variables in the analysis; **product innovation, process innovation, organizational innovation and market innovation.** **Product innovation (inpdt)** is measured through the firm managers' response to the following questions: "During the period 2002-2004, did your enterprise introduce onto the market any new or significantly improved products (goods or services) for your enterprise?" Managers could respond to a 3 point scale where "0 = no", "1 = yes, goods" and "2 =yes, services". Because it is not straightforward in the survey whether managers could tick both "1" and "2", we recoded the variable so that firms with a 1" and / or "2" answerer are counted as product innovators (1=yes, 0 = no).

Process innovation (inpcs) is measured through the managers' response to the following 3 questions in the survey: During the period 2002-2004, did your enterprise introduce any new or significantly improved "production processes", "methods for distribution or supply" and "support systems". Firms answering yes to one or more of these questions are counted as a process innovator (1 = yes). **Organizational innovation (orginn)** is measured through the managers' response to the following three questions in the survey: Please tick whether your enterprise introduced any of the following changes in the time period 2002-2004: "New or significantly improved knowledge support systems", "large changes in work organization, inside the enterprise", and "changes in the relationship to other organizations, such as alliances, partnerships, etc". Firms answering yes to one or more of these questions are counted as an organizational innovator (1 = yes).

Market innovation (markinn) is measured through the managers' response to the following three questions in the survey: During the period 2002-2004, did your enterprise introduce any of the following market innovations "substantial change in product or service design", "new or substantially altered sales or distributions methods", "sales efforts towards new customers or market segments". Firms answering yes to one or more of these questions are counted as a market innovator (1 = yes).

Compared to prior research we will as such analyse whether the "determinants of innovation" differ according to the sub-categories of innovation described above (product, process, organizational and market innovation). Such an approach has been recommended in a recent review (Edquist, 2005). It should also be noted in this context that Reichstein & Salter (2006) argue that process innovation has received too little attention compared to product innovation

in innovation studies. Empirical research on organizational and market innovation is also lacking, although both are central to a Schumpeterian and evolutionary understanding of innovation (Drejer, 2004).

Managers were also asked to state whether their firm had been engaged in **internal R&D**, and **external R&D**, in the 2002-2004 time period (1 = yes). We pose both **internal R&D** and **external R&D** as important determinants of innovation. Most empirical research has in comparison treated R&D as a homogenous indicator. Although this has been criticised in the literature (xxxx), few papers have been able to offer a breakdown of R&D. It is important to offer such a breakdown because both internal and external R&D constitutes different search channels to innovation according to our theoretical perspective discussed earlier. The interrelationship between internal and external R&D is further important for firms' absorptive capacity (Cohen & Levinthal, 1989; 1990) and in open models of innovation (Chesbrough, 2003; Chesbrough et al, 2006).

A predefined set of survey questions referring to the impediments to innovation as perceived by the responding firm managers is also available to us. These variables are used to measure how firms think and perceive the world within the context of industrial innovation. The questions are however directed to the firm management and mainly capture the perceptive abilities or cognitions of the firm management, in most cases the CEO or R&D manager. Managers are however considered to be a very important evolutionary agent and a driving force behind firm behaviour (see Henderson, 2004 for an elaborated discussion).

The following general question was asked: "If your enterprise experienced any hampering factors during the period 2002-2004, please grade the importance of the relevant factors". The respondent could tick more than one of the following hampering factors from 0 = not relevant to 3 = high degree of importance: "Innovation costs too high" (**HCOS**), "lack of finance within the enterprise" (**HFENT**), "lack of appropriate sources of finance from outside the enterprise" (**HFOUT**), "lack of qualified personnel" (**HPER**), "lack of information on technology" (**HTEC**), "lack of information on markets" (**HINF**), "difficult to find cooperation partners for innovation" (**HPAR**), "market dominated by established incumbents (**HDOM**)", and "uncertain supply after new goods and services (**HDEM**)". With these questions we want to explore the relationship between perception and innovation.

We have measured **firm size** by running a principal components factor analysis where standardized indicators of “number of employees” and “turnover”, both measured in 2004, were used as input indicators. One factor was extracted. The details are reported in the appendix. We thus provide a latent measure of firm size because it is not clear-cut whether “sales” or “number of employees” is the best measure to use in this regard. Although there is a large (and old) debate about the role of firm size for innovation in innovation studies (see Cohen, 1995; Cohen & Levin, 1989 for reviews) there has been hardly any debate about what firm size measure to use in empirical research.

We will also control for **group membership** in the analysis. The variable **group** is a dummy and indicates whether a firm is a part of a group or not (1 = yes). The reason for including group as a control variable is that firms with group membership are likely to have access to superior financial resources from a corporate parent.

A central theoretical finding in the literature on the economics of innovation is that the nature of knowledge underlying industrial innovation, technological opportunities, and appropriability conditions differs across industrial sectors (Levin et al 1985; Levin et al, 1987). In order to take this into account we will include industrial sector industry dummies in the analysis (not reported).

5. Analysis

In this section we will analyse the determinants of innovation with a particular emphasis on different types of search activities as potential determinants. In order to do so we will estimate equation 1 below using logistic regression:

$$1) \quad Y_1 = B_0 + B_1X_1 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + B_6X_6 + B_7X_7 + B_8X_8 + B_9X_9 + B_{10}X_{10} + B_{11}X_{11} + B_{12}X_{12} + B_{13}X_{13} + E_1$$

Where Y_1 is one of our 4 binary innovation indicators, for example “product innovation”, X_1 is “external R&D”, X_2 is “internal R&D”, X_3 is “innovation costs”, X_4 is “finance within the enterprise”, X_5 is “finance from outside sources”, X_6 is “qualified personnel”, X_7 is “technological information”, X_8 is “market information”, X_9 is “cooperation partner”, X_{10} is

“market domination by incumbents”, X_{11} is “uncertain demand”, X_{12} is “firm size”, X_{13} is “group” and E_1 is the error term. The actual results are reported in table 5 below.

Table 5. Determinants of innovation

	PRODUCT INNOVATION		PROCESS INNOVATION	
	Beta	OR	Beta	OR
R&D VARIABLES				
External R&D	0,605***	1,83	0,569***	1,77
Internal R&D	2,774***	16,03	1,885***	6,59
INNOVATION OBSTACLES				
High innovation cost	0,297***	1,35	0,305***	1,36
Lack of finance within the enterprise	-0,004	1,00	0,010	1,01
Lack of finance from outside sources	-0,036	0,96	-0,092	0,91
Lack of qualified personnel	0,045	1,05	0,172***	1,19
Lack of technological information	-0,021	0,98	0,199**	1,22
Lack of market information	0,324***	1,38	-0,130	0,88
Lack of co-operation partner for innovation	-0,104	0,90	-0,004	1,00
Market dominated by established incumbents	-0,119*	0,89	-0,087	0,92
Uncertain demand	0,202***	1,22	-0,038	0,96
FIRM FACTORS				
Firm size	0,130**	1,14	0,250***	1,28
Group	0,107	0,90	0,078	1,08
R	0,59		0,37	
N	4165		4165	

*** sig at the 0,01 level, ** sig at the 0,05 level, and * sig at the 0,1 level

Table 5 continued. Determinants of innovation

	ORGANIZATIONAL INNOVATION		MARKET INNOVATION	
	Beta	OR	Beta	OR
R&D VARIABLES				
External R&D	0,569***	1,77	0,347***	1,41
Internal R&D	0,383***	1,47	1,160***	3,19
INNOVATION OBSTACLES				
High innovation cost	0,054	1,06	0,106**	1,11
Lack of finance within the enterprise	0,263***	1,30	0,046	1,05
Lack of finance from outside sources	-0,014	0,99	0,029	1,03
Lack of qualified personnel	0,129**	1,14	0,105	1,11
Lack of technological information	0,137*	1,15	0,076	1,08
Lack of market information	-0,131	0,88	0,218***	1,24
Lack of co-operation partner for innovation	0,027	1,03	-0,145**	0,87
Market dominated by established incumbents	0,186***	1,20	0,175***	1,19
Uncertain demand	0,017	1,02	0,055	1,06
FIRM FACTORS				
Firm size	0,202***	1,22	0,037	1,04
Group	0,579***	1,78	0,150*	1,16
R	0,2		0,27	
N	4165		4165	

*** sig at the 0,01 level, ** sig at the 0,05 level, and * sig at the 0,1 level

In table 5 we can see that both external R&D and internal R&D are positive predictors of product, process, organizational, and market innovation. This set of findings adds to recent papers where the importance of R&D for innovation has been explored (Mairesse & Mohnen, 2005; Crepon et al, 1998). In comparison to prior empirical research our findings demonstrate that both internal and external R&D have a positive influence on the organizational capacity to innovate.

In addition, our results show that internal and external R&D are positive determinants of the organizational ability to innovate in a diverse way. We have found that using retained knowledge and experience in the innovation search process enhance the organizational capacity to innovate with regard to product, process, organizational and market innovation. Hence, both internal and external R&D constitutes strategic search pathways to innovation at the firm level. R&D, with a breakdown by different sub-categories, is as such a main source of firm heterogeneity in relation to industrial innovation.

Contrary to what one might expect we find that “lack of technological information” is a positive determinant of innovation. When firms perceive this obstacle to be a hampering factor they are significantly more inclined to develop both process and product innovations. Although lack of information about technology can pose a serious obstacle to innovation, a responding firm level strategy is to search for such knowledge in order to innovate. Hence, we see that organizational perceptions trigger search activities that are related to the organizational capacity to innovate. Perception of technological obstacles thus leads to creative firm level search processes that are related to innovation (Hugo & Garnesey, 2004).

We also find that “lack of market information” and “uncertain demand” are positive determinants of the organizational ability to develop product and market innovations. When organizations perceive such hampering factors to represent problems of high importance they tend to initiate search activities for new innovations in order to capture new markets and in order to secure new product turnover. Securing profits through product innovation and capturing new markets is a central strategic firm level response to competition in strategic management theory (Teece, 1986; Teece et al, 1996). Hence, firms who perceive “lack of market information” and “uncertain demand” to represent problems of high importance seek to remedy this situation by initiating search activities that positively related to the organizational capacity to innovate. There is as such a nice link between organizational

perceptions of problems and the strategic search responses undertaken by industrial firms. We have as such taken one small step forward in our understanding as to how (perception of) demand is tied to innovation processes at the firm level, something that has been highlighted as a key research topic in innovation studies (Castellacci et al, 2005; Pianta, 2005).

We also find “lack of funding” from within the enterprise to be a positive determinant of organizational innovation. The importance of “funding issues” as an important determinant of innovation has mainly been explored with reference to product innovation and R&D (Hall, 2002). Our findings stand out in slight contrast to this, as we find that perception of funding problems is a positive determinant of organizational innovation. We do as such find that firms aim to overcome innovation funding problems by enhancing knowledge flows inside the company, conducting large scale work-reorganizations, or by getting an external partner or alliance. Getting an external partner might especially by wise innovation strategy that could open up new possibilities. Access to innovation networks and external co - operation partners are generally believed to be an important determinant of innovation (Powell & Grodal, 2005). It is interesting to note in this context that firms perceiving lack of “cooperation partner for innovation” to represent a hampering factor have a significantly lower propensity to develop market innovations. Hence, having access to innovation cooperation partners are an important part of the organizational capability to enter or create new markets.

“Lack of funding” is tied to the perception of “innovation costs” as a hampering factor. When “high innovation costs” represents a perceived problem of higher importance, firms are more inclined to develop product, process and market innovations. Hence, when organizations perceive this innovation obstacle to be a problem, they are significantly more inclined to develop a diverse range of innovations in response. This makes sense from a firm strategic and behavioural point of view: While product innovations can capture new markets together with market innovations, process innovations reduce costs (Fagerberg, 2005; Pianta, 2005; Drejer, 2004). Firms who perceive innovation costs to represent an impediment to innovation thus bundle different types of innovations together in order to secure new product turnover, capture new markets, and reduce production costs.

It is further interesting to note that when firms perceive the “lack of qualified personnel” to constitute an innovation obstacle of higher importance, they are significantly more inclined to develop both process and organizational innovations. Again, this makes sense from a strategic

firm point of view: Process innovation reduce the demand for labour in the organization while organizational innovations reorganize work practices within the firm (Pianta, 2005; Verspagen, 2004; Drejer, 2004). There is as such a nice “micro-link” at the firm level between perception of problems and the types of innovations developed to solve the perceived problems.

Understanding the role of innovation in relation to industry entry barriers has also been highlighted as important by reviews of the literature (Geroski, 1995; Audretsch, 2001). A central question in this regard has been whether firms are less inclined to innovate and are deterred from market entry in industries dominated by incumbents. According to the results presented in table 5 there are some “truth” to such arguments as the perception of market dominance is a negative predictor of product innovation. This can arguably be due to the presence of industry standards that generally goes together with entrenched market structures and dominance by large incumbents (Klepper, 1997; Utterback, 1996). But this does not mean that firms with such perceptions are inert and unable to change in response to entrenched market structures. Firms who perceive that their market is dominated by established incumbents aim in fact to destroy existing market structures or to create new markets by developing organizational and market innovations in response. These findings demonstrate that it is important to include other types of innovations apart from process and product innovation in order to better understand how organizational cognitions constitute a source of firm heterogeneity in relation to innovation. It also suggest that organizational and market innovations are an important element of “creative destruction processes” (Schumpeter, 1934; Drejer, 2004).

In order to sum up: What do these results imply for evolutionary and behavioural understandings of firm heterogeneity? At a higher theoretical level our results imply that both R&D and organizational cognitions constitute different types of search pathways to innovation at the firm level. We have seen that both internal and external R&D enhance the organizational capacity to develop product, process, organizational and market innovations. In contrast to prior empirical research we have documented that both internal and external R&D constitutes distinct search pathways to different types of innovations at the firm level. Using retained knowledge and experience in the innovation search process thus enables firms to innovate, as argued in evolutionary and behavioural theory (Nelson, 1961; Nelson & Winter,

1982; Nelson, 1995; March, 1991). Both internal and external R&D is as such important sources of firm heterogeneity in relation to innovation.

Our results also suggest that perception of problems trigger organizational search processes, as argued by evolutionary and behavioural theories of the firm (Cyert & March, 1963; Nelson & Winter, 1982). Organizational search efforts based on perceptions of problems are however related to innovation in different ways. Some perceptions, like “innovation costs”, are positively related to both product and process innovation. Other perceptions, like “lack of market information”, are positive predictors of the organizational capacity to develop market innovations. Yet other types of organizational cognitions, such as “lack of qualified personnel” are related to the ability to develop organizational innovations. What emerges from these findings is that organizational cognitions are an important source of firm heterogeneity in relation to innovation. There is as such a nice “micro-link” at the firm level between perception of problems and the types of innovations developed to solve the perceived problems.

6. Conclusion

The main objective in this paper has been to analyse firm heterogeneity in relation to innovation at the firm level. In order to provide such an analysis, we have taken a closer look at how industrial firms search for new knowledge, technology and innovation. Organizational search processes are believed to be the main driving force behind innovation at the firm level in evolutionary and behavioural theories of the firm. Our empirical understanding of firm heterogeneity and organizational search in relation to innovation in this regard is lacking however.

We have focused on two main categories of search in this paper in order to provide an empirical analysis of firm level heterogeneity in this regard: Both R&D and organizational perceptions are in our theoretical framework empirical manifestations of organizational search processes for (different kinds of) innovations. Our results show that (different types of) R&D and organizational perceptions constitute distinct search pathways to a diverse range of innovations at the firm level. Both R&D and organizational perceptions are positively related to the organizational capacity to develop product, process, organizational and market innovations.

Our main contribution to the literature is empirical, as empirical research lags behind theoretical understandings of firm heterogeneity in relation to innovation in evolutionary economics. Hence, we have empirically demonstrated that firms use a range of distinct search pathways in order to innovate.

Appendix

Table A1. Correlation matrix between innovation obstacles, internal and external R&D

	Innovation costs	Finance Within enterprise	Finance from outside	Qualified personnel	Info. on tech.	Info. on markets	Coop. partner	Market Dom.	Uncertain demand	Internal R&D	External R&D
Innovation Costs	1										
Finance within enterprise	0,75*	1									
Finance from outside	0,69*	0,78*	1								
Qualified Personnel	0,57*	0,58*	0,56*	1							
Information on tech.	0,61*	0,57*	0,55*	0,7*	1						
Information on markets	0,6*	0,58*	0,58*	0,66*	0,76*	1					
Cooperation Partner	0,55*	0,56*	0,59*	0,61*	0,68*	0,68*	1				
Market domination	0,57*	0,5*	0,48*	0,52*	0,56*	0,59*	0,58*	1			
Uncertain Demand	0,45*	0,51*	0,5*	0,55*	0,58*	0,64*	0,56*	0,67*	1		
Internal R&D	0,45*	0,42*	0,4*	0,36*	0,38*	0,38*	0,3*	0,25*	0,31*	1	
External R&D	0,3*	0,28*	0,27*	0,25*	0,28*	0,27*	0,24*	0,16*	0,2*	0,62*	1

* Sig at the 0,01 level

Table A2. Correlation matrix between binary innovation indicators

	PRODUCT INNOVATION	PROCESS INNOVATION	ORGANIZATIONAL INNOVATION	MARKET INNOVATION
PRODUCT INNOVATION	1			
PROCESS INNOVATION	0,47*	1		
ORGANIZATIONAL INNOVATION	0,26*	0,34*	1	
MARKET INNOVATION	0,45*	0,34*	0,36*	1

* Sig at the 0,01 level

Table A3. Factor analysis using number of employees and turnover as input variables (standardized variables)

Measures of firm size	Factor loadings
Number of employees	0,899
Turnover	0,899
Cumulative % of explained variance	0,81

