Firm heterogeneity within industries: How important is "industry" to innovation?

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Abstract

In this paper we assess how important "industry" is to innovation. Our empirical estimates suggest that "industry factors" matter little to how firms' search for new innovations. These results offer empirical support to recent evolutionary theory where firms have heterogeneous capabilities and pursue different approaches to innovation. Structural variables at the industry level do however have a substantial influence on the firm level propensity to innovate. This result supports "sectoral innovation system" approaches where firms are "constrained" by technological regimes underlying industry evolution. Hence, the driving forces behind technological evolution are found at both the firm and industry level.

1. Introduction

An important building block in evolutionary theory is the notion that firms pursue different learning activities, have different approaches to innovation, and hence vary in terms of performance (Nelson, 1991; Nelson, 1995; Winter, 1984;2003; Teece, 2007). Prior research in evolutionary economics has in some contrast sought to demonstrate that firms within the same industry share similar characteristics, knowledge bases, and tend to pursue the same kinds of innovation strategies due to technological regimes and sectoral innovation systems underlying industry evolution (Nelson & Winter, 1982, Malerba & Orsenigo, 1996; Breschi et al, 2000; Malerba, 2005).

There is as such a *potential conflict* between the literatures on "technological regimes" and "sectoral innovation systems" where it is argued that firm behaviour is determined by industry characteristics on the one hand, and recent evolutionary theorizing stressing firm heterogeneity on the other hand (Leiponen & Drejer, 2007). This *potential conflict* is an illustration of the argument that recent advances in evolutionary theory lack an empirical basis (Fagerberg, 2003). Lack of "empirical basis" 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 for discussions).

A main aim in this paper is to shed some empirical light over this potential conflict in innovation studies between "firm heterogeneity" on the one hand, and the notion of an industry representative firm found in the literatures on "technological regimes" (Malerba & Orsenigo, 1996; Breschi et al, 2000), "sectoral patterns of technical change" (Pavitt, 1984; Marsili & Verspagen, 2002) and "sectoral innovation systems" (SIS) (Malerba, 2005) on the other hand. This issue touches upon the decade's long debate in the social sciences between the relative importance of *actor* and *structure* for explaining socio-economic phenomena (see Ritzer, 2000). In innovation studies however, this issue has remained poorly examined (Castellacci et al, 2005; Castellacci, 2007ab; Nelson, 2006).

A core research issue in this regard is the extent to which firms within the same industry differ from one another (Malerba, 2005). What we know is that firms within the same industry differ widely in terms of performance and profitability. Research on this issue has found that

industry membership accounts for roughly 20 % of the total variance in firm performance. The remaining residual variance is found elsewhere, the majority at the firm level (Rumelt, 1991; McGahan & Porter, 1997; Powell, 1996). According to this "profit decomposition literature" firms within the same industry seem to have heterogeneous performance.

But what are the sources of heterogeneous performance at the firm level? Although evolutionary and resource based theories argue that diversity in performance stems from differences in innovative capabilities across firms (Nelson, 1991;1995; Teece et al, 1997; Teece, 2007; Winter, 2003;Barney, 1991), research on this subject matter is lacking (Fagerberg, 2003). This is an issue we intend to tackle in this paper by empirically assessing whether firms within the same industry are different from one another in their approach to innovation and have different outcomes from innovation processes. This is examined with reference to different types of innovations (incremental and radical product innovation, process innovation), innovative performance (share of turnover from new innovation), R&D spending (internal and external) and different types of innovation obstacles.

An empirical assessment of this sort is a "missing link" in the literature: Although we know that firms have heterogeneous performance, we do know how such differences emerge in the first place. Although it is argued that heterogeneous performance is due to heterogeneous innovative capabilities and perceptions (Nelson, 1991; 1995; Cyert & March, 1963), empirical research on this issue is lacking (Fagerberg, 2003).

There is one recent exception to this however. In a nice study from Denmark and Finland Leiponen & Drejer (2007) have documented the existence of considerable firm heterogeneity within industries in relation to the types of innovation strategies firms pursue. Leiponen & Drejer (2007) examine heterogeneity within industries for the sub-sample of innovating firms. Our analysis will complement this recent study by taking all firms into account, innovators as well as non-innovators. Hence we react to recent developments in the literature, and to the general argument that it is important to include also non-innovative firms in empirical analysis of firm heterogeneity (Archibugi, 2001; Evangelista & Mastrostefano, 2006). Innovation is after all the "outcome" that innovation studies aim to understand. Focusing solely on innovating firms will provide a biased understanding of innovation. We will therefore include non-innovators in the analysis.

We also use a quantitative multilevel modelling technique that explicitly addresses the extent to which firms are different from one another within the same industry. We have chosen to look at the firm versus the industry level because analysis of sectors and industries has been important to the development of innovation studies. This is reflected in the literatures on "technological regimes", "sectoral patterns of technical change" and "sectoral innovation systems". But despite the industry focus in these literatures, the notion of firm heterogeneity has always been important in Innovation Studies. As an example, Pavitt himself noted that there was a great deal of firm variety within each of the four sector categories in his well-known taxonomy (Pavitt, 1984; Archibugi, 2001). Empirically however, "firm heterogeneity" has remained little researched.

An important question that emerges is then "how important is industry to innovation"? The relative importance of industry and firm factors for profitability has been a fundamental research issue in economics and strategy (McGahan & Porter, 1997). With this paper we extent the same research issue to Innovation Studies. An empirical assessment of how important industry factors are to innovation is thus warranted. Why this is a fundamental issue in Innovation Studies is discussed in more detail section 2. The multilevel modelling technique we use to assess the importance of industry to innovation is discussed in section 3. We discuss the results in section 4 where the analysis is undertaken. We draw some conclusions and implications for further research in section 5.

2. Innovation and performance

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). 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.

2.1 Firm heterogeneity and technological regimes

Given the importance of "diversity" in evolutionary theory it is interesting to note that empirical analysis of firm heterogeneity is rather absent in evolutionary economics (Fagerberg, 2003; Malerba, 2005). Research in this tradition has on the other hand studied inter-industry differences in innovative activities. An early line of research in this tradition focused on the effect of market structure variables for explaining industry level R&D intensity. This literature has to a large extent been based upon the Schumpeterian hypothesis and the argument that R&D intensity is significantly influenced by industry concentration and market structure variables (Klevorick et al 1995: Levin et al, 1985; Kamien & Schwartz, 1975; Cohen, 1995; Cohen & Levin, 1989). Later studies has extended this research by arguing that industry R&D intensity is not primarily driven by market structure variables, but by differences in technological opportunities and appropriability conditions across industries (Levin et al, 1985; Klevorick et al, 1995).

A rather large empirical literature has documented that inter-industry variations in technological opportunities and appropriability conditions are significantly related to differences in R&D intensity at the industry level. For instance, Levin et al (1985) tested the Schumpeterian hypothesis by using the Yale survey. Although they found a weak but positive relationship between industry concentration and industry R&D intensity one the one hand, and industry concentration and innovation rates[1] on the other hand, these relationships vanished when they controlled for industry differences in technological opportunities and appropirability conditions. The same authors found in a later paper that industry characteristics, including appropriability, technological opportunities and demand conditions, explained 56 % of the between industry variation in business unit R&D intensity (Levin et al, 1987).

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[1] New products and processes

The importance of technological opportunities for explaining industry R&D intensities have more recently been confirmed by Klevorick et al (1995). Using aggregated data for 25 industrial sectors at the 2 and 3 digit industry level they found important differences in R&D intensity across industries, and further, that the sources and strength of technological opportunities could explain the cross-industry variation in R&D intensity.

Inter- industrial differences in technological opportunities and appropriability conditions have further been important to the empirical literature on technological regimes. This literature builds on Nelson & Winters (1982) argument that the nature of technology set boundaries to the pattern of industrial competition and innovation. A central part of Nelson & Winters argument is that learning processes and search activities at the firm level are constrained by the technological environment or the prevailing technological regime.

Research on technological regimes and Schumpeterian patterns of competition has provided important insights into why and how sectors differ in terms of innovative activities. Malerba and Orsenigo (1996) and Breschi et al (2000) have verified the existence of two technological regimes identified by Nelson & Winter (1982) and related them to a Schumpeter Mark 1 and Mark 2 pattern of industrial competition. Other researchers have been inspired by Pavitts (1984) inherently more empirical attempt to construct a sectoral taxonomy of technical change using manufacturing data at the two digit industry level from the UK. In his work Pavitt (1984) aimed to describe and explain similarities and differences among industrial sectors in the sources and nature of technology, and by the characteristics of innovating firms.

Marsili and Verspagen (2002) have in more recent work proposed and successfully tested a classification of technological regimes that refine Pavitt's (1984) taxonomy using data from Dutch manufacturing industries. This classification identifies five technological regimes as a disaggregate alternative to the dichotomized versions of technological regimes previously proposed (Schumpeter Mark 1 versus Mark 2). Castellaci (2007c) has further verified and extended the Pavitt taxonomy using industry data from several European countries. Lastly, the "sectoral innovation systems" approach has united many of these insights as it is argued that industrial sectors differ in terms of the underlying knowledge-bases, types of actors and interactions, and the institutions that govern these (Malerba, 2005; Evangelista & Mastrostefano, 2006).

Distinct to the above literature on technological regimes and sectoral patterns of technical change is the notion that industrial sectors varies in terms of the sources, incentives and effects of innovation (Nelson & Winter, 1982; Pavitt, 1984; Dosi; 1988; Malerba & Orseniego, 1996; Breschi et al 2000; Klevorick, et al 1995; Levin et al 1987; Malerba, 2005). What emerges from this literature is that firms within the same industries share the same innovation characteristics, knowledge bases, and tend to pursue the same kinds of innovation strategies due to underlying similarities in technological regimes (Nelson & Winter, 1982), sectoral patterns of technical change (Pavitt, 1984), and sectoral innovation systems (Malerba, 2005).

In our view there is a *potential* conflict between recent evolutionary theorising where "firm heterogeneity" is important and empirical research on "technological regimes" and "sectoral innovation systems" where it is more or less assumed that firms within the same industry are similar to each other. Although the "technological regimes" and "sectoral innovation systems" literatures stress the importance of limited rationality and heterogeneity in their approach to innovation, the literature nevertheless portray firm behaviour as determined by industry factors (Leiponen & Drejer, 2007). To what extent is such a notion of an "industry representative firm" at odds with recent evolutionary theorizing?

The above discussion and "potential conflict" is an illustration of the argument that 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 for discussions). Hence, it is important to advance empirical research on this subject matter in order to improve our theoretical understanding of innovation. A main aim in this paper is to provide an empirical connection back to evolutionary theory where processes associated with the theoretical core in evolutionary economics (e.g. firm heterogeneity) are analyzed empirically. Such firm heterogeneity has been detected, not in relation to innovation, but in relation to profitability.

2.2 Firm heterogeneity and profitability

An interesting research tradition – the "profit decomposition literature" mentioned earlier - has attempted to unravel whether the sources of firm profitability reside at the industry or firm level. This profit decomposition literature has been motivated by the competing explanations

set forth by resource based theory and the industrial organization literature as to where the main source of firm profitability is located. The industrial organization literature has generally followed the structure-conduct-performance paradigm associated with Bain (1956) and argued that differences in firm profitability stems from industry structure. The main bulk of this research has sought a link between industry concentration, entry barriers and industry profitability (Rumelt, 1991).

Some strategy researchers have also looked to the industry level when the main sources of firm profitability have been discussed. Arguably the most famous perspective in this regard is the competitive forces approach developed by Porter (1980). This approach is inspired from the structure-conduct-performance paradigm and argues that industry structure strongly influences the competitive rules of the game, as well as the set of strategies that are available to firms.

Especially five industry level forces – entry barriers, threat of substitution, bargaining power of suppliers, and rivalry among incumbents – are believed to determine the strategies available to firms and their profit potential (Teece et al, 1997). Superior performance is in this perspective "a function" of firms' ability to find an easily defendable position in an industry and / or to influence the competitive forces in the firm's favor. Summing up, both the IO literature and the competitive forces approach argue that the main sources of firm profitability are located at the industry level.

Strategic management research has in contrast offered a competing view where profitability stems from resources, capabilities and actions that are unique firms (Barney, 1991; Rumelt, 1984; Wernerfelt, 1984; Teece et al, 1997; Teece 2007; Winter, 2003). The resource based approach argues that firm profitability is not so much determined by "industry factors" but rather stems from firms' ability to develop – and use - specific competences and capabilities to reduce costs or to create high quality products (Teece et al, 1997). Such resources and capabilities are sources of sustained competitive advantage due to their firm specific and difficult to imitate nature (Nelson; 1991; 1995; Teece, 2007). Resource based theories argue that idiosyncratic resources specific to firms determine profitability. Hence, the sources of profitability are located at the firm level in this theoretical context.

A small empirical literature has accordingly examined whether the sources of profitability reside at the industry or the firm level. Using accounting – and perceived – performance measures, Schmalansee (1985), Wernerfelt & Montgomery (1988), and Powell (1996) have decomposed the total variance in business unit performance due to industry and firm factors, using cross sectional data. These studies have shown that roughly 20 % of the variance in firm performance is due to industry factors. The remaining residual variance was unrelated to industry membership and mainly located at the firm level[2].

Rumelt (1991) clarified this issue further by decomposing the variance in business unit profitability due to "stable industry" and "stable business unit" effects, using the same data source as Schmalansee (1985) and Wernerfelt & Montgomery (1988). Using a longitudinal approach (1974 - 1977), he showed that long term industry effects accounted for only 8 % of the observed variance, but that stable business unit effects accounted for 46 %[3]. Based upon these results, Rumelt argued that because the most important sources of economic rents are business specific and stable over time the "classical focus upon industry analysis is mistaken". In Rumelt's view these results offer strong empirical support to strategic management research stressing "firm heterogeneity".

In a more recent paper McGhan & Porter (1997) have criticized Rumelt's (1991) study for not taking services sectors into account. In an analysis that included both manufacturing and service industries they found that industry factors accounts for 19 % of variance in profitability at the firm level. This result is however in line with other results in the literature.

According to Nelson (1995), evolutionary theory is consistent with this "profit decomposition literature" that has documented the existence of considerable and persistent intra-industry inter-firm differences in profitability and growth rates. Although evolutionary theory is *consistent* with studies documenting a large intra-industry variance in performance among firms in the same industry, this *consistence* has not been analyzed empirically. This is a main aim in this paper. To what extent are firms within the same industries similar to one another when it comes to R&D spending, perception of innovation obstacles, innovation, and

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[2] Cooperate factors were also analyzed but these were either small, or non-existing.
[3] Using the same sample of firms as Schelmalese, but for the time period 1974-1977, Rumelt (1991) found that 8 % of the total variance in business unit profitability was due to industry factors, 1 % were due to corporate factors, 46 % were due to business unit effects, 8 percent due to industry-year effects, and 37 percent were residual error.

innovative performance? Below we will briefly discuss each group of variables in relation to how they shed empirical light over important issues in Innovation Studies. We will start with R&D.

2.3 Research and development

Nelson & Winter (1982) have proposed that search routines and processes are the main driving forces 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). An important question that emerges is to what extent firms in the same industry have the same search routines and follow the same approach to innovation. It turns out that this is not an easy question to answer, partly because there is no clear-cut way of measuring "search routines".

Research on organizational routines suffers from conceptual ambiguity when it comes to how search routines should be defined 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-empirical analysis of firm behaviour. In this paper the aim is to take a closer look at the learning and search activities firms undertake in order to find solutions to problems and to innovate, 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?

In this paper 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 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. We will thus use R&D activity as an empirical measure of the organizational ability to execute deliberate learning and search activities for new technologies and knowledge (Nelson & Winter, 1982; Carroll & Hannan, 2000). It is thus a central aim in this paper to examine whether firms within the same industry differ from one another in terms of R&D based search behaviour.

2.4 Perceptions

A related evolutionary notion is the theoretical idea that firms are able to change their knowledge base through search activity when they perceive 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. Firms also differ in the ways they perceive the world (Fagerberg, 2003). How is this related to innovation?

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 choose to become entrepreneurs due to differences in talents and psychological attributes (Fagerberg, 2003). Hence, an important source of firm heterogeneity is related to differences in "psychological attributes" across firms, e.g. differences in how organizations think and perceive the world (Fagerberg, 2003).

It is well established in evolutionary and behavioural theory that firms have different cognitions and perceptions (Nelson & Winter, 1982; Nelson, 1991; Cyert & March, 1963). Differences in perception and cognition arise because firms are boundedly rational and lack perfect information (Cyert & March, 1963; Nelson & Winter, 1982). Innovation is in this context 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). How is perception related to search?

In the behavioural theory of the firm, organizations initiate search efforts in relation to managerial perception of problems (Cyert & March, 1963; Greve, 2003). *Perception* of problems is thus a key issue in relation to search and innovation at the firm level. But to what extent do firms within the same industry have the same kinds of perceptions? Do they perceive the same problems to be important? According to the literature on technological regimes, managerial perception of problems and the problem solving activity undertaken by industrial enterprises will be constrained by the prevailing technological paradigm embedding their industry. This can lead to path-dependence and "lock-in" to a limited set of technological alternatives (Dosi, 1982).

Recent evolutionary theorizing argues in some contrast that firms have different perceptions and cognitive abilities. "Cognitive abilities" thus emerge as an important source of firm heterogeneity. If firms have different perceptions, they will also initiate different organisational learning efforts and pursue heterogeneous search paths for new innovations (Dosi et al, 1997; Dosi & Marengo, 2007). If this latter perspective is correct, managers within the same industry will have different cognitions and perceptions. Because such heterogeneity is related to search and innovation, "past-dependencies" and "lock-in" to a limited set of technological alternatives can be avoided within an industry. Although theoretical research on these issues has been important to innovation studies and discussions of "past-dependency" (Arthur, 1989; David, 1985), little empirical research has been conducted so far.

A main aim in this paper is simply to take an empirical approach to the above issue in order to "assess" how important industry factors are for firms "outlook" and perception of problems in relation to innovation. This can shed important insight over how "constrained" firms are by their industry context and the technological regime underlying industrial evolution.

2.5 Innovation and innovative performance

Innovation is of vital importance to evolutionary models of economic change. Technological change is in this framework an outcome of investments made by business firms to compete and beat their rivals (Nelson, 1995). Economic development occurs in this context through a process of creative destruction where new innovations destroy the competence of established firms and disrupt existing industry structures (Link, 1980). But are the sources of creative destruction located at the firm or the industry level?

Although it is argued that firms follow different approaches to innovation (Nelson, 1991; 1995; Teece et al, 1997; Barney, 1991), it is also argued that they type of innovation firms develop are influenced by industry-life cycles (Klepper, 1997; Utterback, 1996) and the technological regime underlying industry evolution (Malerba & Orsenigo; 1996; Breschi et al 2000; Nelson & Winter, 1982).

According to "industry-life cycle" and "technological regime" perspectives firms should be far more inclined to develop process and incremental product innovations if they belong to a mature industry or a Schumpeter Mark 2 type of technological regime (Klepper, 1997). Firms

should on the other hand be far more inclined to develop a radical innovation in the early phases in the industry life cycle when an entrepreneurial technological regime dominants the pattern of innovative activity in the industry (Utterback, 1996; Klepper, 1997).

This brief discussion demonstrates that there is some confusion in relation to whether the sources of creative destruction (innovation) are located at the firm or the industry level. To what extent is the organizational capacity and ability to develop different kinds of innovations determined by the industry-life cycle and underlying technological regimes? Do firms also introduce radical product innovations in "mature" industries? As we have discussed above, both strategic management research (Teece et al, 1997; Barney, 1991; Wernefelt, 1981) and evolutionary theorists (Nelson; 1991; 1995) argue that firms follow different approaches to innovation due to heterogeneous perceptions and search capabilities. If this latter perspective is correct, firms within the same industry should be different from one another also in relation to what types of innovations they develop.

We will also look at whether firms in the same industries share similarities in terms of their innovative performance (turnover from new product innovations). Turnover from new product innovation is a measure of whether the innovations firms develop are being favoured by the market, which is an important aspect of the process of creative destruction described by Schumpeter (1934). Variables measuring this aspect of the innovation process will also provide an empirical link to the profit decomposition literature. Although this literature has looked at profitability, there might be some consistence between new product turnover and profitability.

Innovation and innovative performance are arguably the most important domains of variety in evolutionary economics (Evangelista & Mastrostefano, 2006). It is thus important to take a fresh look at whether firms in the same industry are different from one another when it comes to innovation and innovative performance. Is recent evolutionary theorizing "correct" in emphasising "firm heterogeneity" or is the notion of industry representative firm in the literatures on technological regimes and sectoral patterns of technical change more correct?

3. Method and data: Multilevel modeling and nested data

Evolutionary scholars have generally argued that innovation is a multilevel phenomenon (Aldrich, 1999; Hodgeson, 1993). Because innovation has an inherently multilevel character, variables at different levels of analysis can have an influence on innovation processes at the firm level (Castellacci et al 2005; Castellacci, 2007ab). Empirical research have in some contrast to this theoretical insight mainly focused on one – and not several - analytical levels when trying to explain innovation and technological change. In this paper we use a multilevel modeling technique that enables us to test the relative importance of competing theoretical explanations at different levels of analysis. As discussed above, this paper is motivated by the potential conflict in Innovation Studies about whether the sources of innovation are located at the firm or the industry level.

A statistical reason for using multilevel modeling is that the technique is designed to analyze nested data, for instance where firms are nested within industries as in our case. If this nested data structure is ignored, estimates are likely to be biased as the usual regression assumption that observations are independent of each other can be (strongly) violated. Although this can be taken into account in the ordinary regression framework, multilevel modeling is attractive mainly for the theoretical reason discussed above: Innovation is believed to be a multilevel phenomenon.

In this paper we will use a simple multilevel model, a two level "intercept only model" (Hox, 2002). The "intercept only model" decomposes the total variance of a dependent variable, for instance an indicator of innovation, into an industry and a firm component. The relative "size" of these two components informs the researcher about whether the sources of innovation are located at the industry or the firm level.

It is in this context important to stress that our aim is not to analyze how variables at different levels influence innovation. We are only interested in the relative importance of industry and firm effects – however generated – for explaining the variance in innovative activities at the firm level (see Rumelt 1991 for a nice discussion). Hence, we will not attempt to explain the decomposed variance, which will remain essentially "unexplained". Such a variance decomposition analysis provides a purely descriptive - but yet very intuitive – measure of how

important industry factors are for explaining innovation at the firm level. Statistically a "two level intercept only model" is described as follows:

$$Y_{ij} = y_{00} + u_{0j} + e_{ij}$$

Where Y_{ij} is the value on the dependant variable (for instance innovation) for firm "i" in industry "j". Further, y_{00} is the intercept (and the grand mean), and u_{0j} and e_{ij} are residual terms at the industry and firm levels respectively. The variances of the residual terms are given by σ^2_{uo} and σ^2_{e}. In order to estimate the relative importance of "industry" and "firm" factors for innovation and performance at the firm level we will calculate the Intraclass Correlation Coefficient (ICC). The ICC coefficient measures the proportion of variance in the dependent variable that is accounted for by higher level units (Luke, 2004). In our case "industry" is the highest level unit. When the primary goal is to decompose the variance across two different analytical levels (industry & firm), the ICC is calculated as follows (Hox, 2002; Luke, 2004):

$ICC_{industry} = \sigma^2_{uo} / (\sigma^2_{uo} + \sigma^2_{e})$, which estimate the proportion of the variance in the dependent variable that is accounted for by industry factors. The remaining residual variance will thus be accounted for by firm level factors. We use SPSS and MLWIN to calculate the ICCs.

It should be noted in this context that decomposing the variance in binary indicators is not a straightforward exercise (Hox, 2002; Luke, 2004). This applies mainly to our indicators of product and process innovation, which are binary variables. We have tackled this issue by using both logit and binary linear models to decompose the variance in our binary innovation indicators and then compared the results. This is discussed in more detail below.

3.1 Data and the dependant variables

The research in this paper draws on a novel database. The main part of the data is based upon the third version of the Community Innovation Survey (CIS 3) and a R&D survey, both for Norway. This combined survey contains large amounts of information about firm's innovation activities (CIS survey) and questions about how firms finance their R&D activities (R&D survey). The questionnaire was administrated by Statistics Norway and directed to a representative sample of Norwegian firms with 10 employees or more. It was returned by 3899 firms which constitutes a response rate of 93 %. A novelty with our survey data is that

R&D spending was collected also for non-innovative firms. In many other countries information about R&D spending is only collected for innovative firms within the context of the CIS survey.

We are fortunately able to overcome this problem. It is important to overcome this problem because there has been a tendency in innovation studies to look at only innovating firms in discussions and studies of "firm heterogeneity" (Evangelista & Mastrostefano, 2006; Archibugi, 2001). In this paper we have chosen to focus at the 2.digit industry level (2.digits NACE) because the CIS survey is representative at this industry level. Our 3899 firms are nested within 42 two digit NACE industries.

In the section below we analyse the relative importance of industry and firm factors for innovation using a broad range of innovation indicators, such as internal and external R&D, product and process innovation, and new product turnover from innovation. The variables are defined in table 1.

[Table 1 about here]

4. Analysis

In tables 2-5 we have partitioned the total variance in a range of indicators measuring perception of problems, search activity, and innovation into a firm level and an industry level component. Let us start the discussion by looking at whether managers within the same industry perceive the same problems to be problematic. These results are reported in table 2.

[Table 2 about here]

Let us start by explaining table 2. In the first column we have partitioned the total variance in the variable "perception of high economic risk" into an industry level and a firm level component. These variance components are given by "σ^2_{uo}" and "σ^2_e" respectively (standard error for these components are reported in the parenthesis). The ICC coefficient in this particular case is given by $(0.07) / (0.07 + 1.26) = 0.05$. Multiplied with 100 this is the percentage of the variance in the variable "perception of high economic risk" accounted for by industry factors. The remaining residual variance is accounted for by firm factors. An

interpretation of this particular result is as follows: Take all relevant industry factors into account and they can explain at most 5 % of the variance in the managerial perception of high economic risk as an obstacle to innovation. Hence, industry variables seem to matter little as to why managers within the same industry perceive economic risk to represent a problem in relation to innovation.

Perception of economic risk is not an "odd case" in this regard. In table 2 we can see that "firm factors" are far more important than "industry factors" for explaining the variance in all the perception variables. Managerial perceptions of "high economic risk", "too high innovation cost", "organizational rigidities", "lack of qualified personnel", "lack of technological and market information", "too strong regulation" and "lack of customer interest" seem to have little to do with industry membership and characteristics of firms' industry environment.

[Table 3 about here]

In table 3 we have decomposed the total variance in internal and external R&D intensity into an industry level component and a firm level component. The Intraclass Correlation Coefficients suggest that 7 % of the total variances in these two indicators are accounted for by industry factors. Hence, the remaining residual variance is found at the firm level. This result offer empirical support to recent evolutionary theorizing where it is argued that firms have widely different R&D capabilities and develop unique assets and competencies (Nelson, 1991; 1995; Teece et al, 1997; Teece, 2007; Winter, 2003; Barney, 1991). But are industry factors important for the organizational ability to innovate? In table 4 we take a closer look at this issue.

[Table 4 about here]

In table 4 we have done a variance-decomposition analysis using a logistic regression model. For such binominal models the reported variance at the lowest level is 1. In the binominal distribution the lowest level variance is completely determined when the mean is known. Therefore the lowest level variance in such contexts has no useful interpretation. By default this variance is fixed to 1 (called a scale factor), which is equivalent to the assumption that the binominal distribution holds exactly (Hox, 2002). The variance of a logistic distribution with

scale factor 1 is 3.29. This figure, 3.29, can then be used to calculate the ICC coefficient (Hox, 2002). We have reported such calculations in table 4. As is reported in table 4, "industry factors" account for between 9-14 % of the variance in innovative activities (product & process innovation) at the firm level.

The above calculations assume however that the lowest level variance in our dependant variables follow the binominal distribution exactly. It is possible to estimate the "real" scale factor in order to shed empirical light over this assumption. We have done this for our binary innovation indicators in table 4. It turns out that the estimated scale factors are less then 1. This means that our models suffer from under-dispersion. Under-dispersion in our case means that the estimate for the lowest level (firm) variance is lower than expected. If the variance at the lowest level is less than expected, the ICC coefficients we have calculated in table 4 should in reality be higher. Thus, we may have overestimated the reported lowest level variance in table 4.

Because there are reasons to suspect that the lowest level variance reported in table 4 have been overestimated, we have run a variance-decomposition analysis on the same set of binary innovation indicators using a binary linear model. Although such a method assumes that the binary variables are normally distributed (which is an unrealistic assumption), this method provides a rough approximation to the ICC coefficient. We have reported this analysis in the appendix. An interesting result in this context was that the ICC coefficient for "new to the firm innovation" was 23 %.

The results demonstrate the "industry factors" account for between 9 to 23 % of the variance in innovative activities at the firm level. Hence, "industry factors" are moderately important for the organizational ability to innovate, especially in relation to incremental product innovation. Although industry characteristics are not so important for managerial perceptions of innovation obstacles and R&D intensity at the firm level, industry factors are important for especially product innovation. This finding suggests that "technological regimes" and "sectoral innovation systems" do not constrain firms in how they perceive the world and search for new innovations. But on the other hand, the nature of technology actually set some boundaries to what firms actually can discover when it comes to developing new innovations.

What emerges is that "technological regimes" (Malerba & Orsenigo, 1996; Breschi et al, 2000), "sectoral patterns of technical change" (Pavitt, 1984) and "sectoral innovation systems" (Malerba, 2005) have a substantial influence on the organizational capacity to innovate, especially when it comes to incremental product innovation. But what about turnover from new product innovations?

[Table 5 about here]

In table 5 we have decomposed the variance in two indicators of innovative performance: "Turnover from innovations new to the firm", and "turnover from innovations new to the market". The Intraclass Correlation Coefficients for these two innovation indicators suggest that industry factors account for 11 % and 21 % of the total variance in innovative performance at the firm level. The dependent variables in table 5 are skewed because many non-product innovators report "0" in turnover from new innovations. In order to explore whether this introduces some noise in the analysis we ran the same multilevel model as reported in table 5, but using the sub-sample of product innovators. The results were roughly similar. Results are reported in the appendix for the interested reader.

The results presented in table 5 are consistent with the findings from the "profit decomposition" literature where about 20 % of firm profitability is due to industry factors. What emerges from these results is that "industry factors" are moderately important for firms' ability to reap the economic returns from new product innovations. The remaining residual variance is however high. This is consistent with recent evolutionary theorizing and resource based theory where it is argued that firm specific competences and capabilities are far more important than industry factors for the organizational ability to profit from innovation (Teece et al, 1997; Teece, 2007; Barney, 1991; Nelson; 1991; 1995; Winter, 2003).

The results reported in tables 2-5 provide an empirical confirmation of recent evolutionary and resource based theorizing where it is argued that firms have unique assets, develop different capabilities and hence differ in terms of performance (Nelson, 1991; 1995; Teece et al, 1997; Teece, 2007). Our empirical estimates suggest that research on "technological regimes" and "sectoral systems of innovation" capture between 7- 23 % of the variance in R&D and innovative activities at the firm level using industry data. Firms within the same industry are in other words 7-23 % similar to each other with respect to R&D and innovation.

This "similarity" in firm behaviour is what empirical research using industry data capture. Hence, there is a high degree of firm heterogeneity within sectors and technological regimes.

Most of the empirical research on "technological regimes" and "sectoral innovation systems" has been done using industry data and industrial classifications. One might wonder whether empirical research is able to capture the central theoretical dimensions of the concepts "technological regimes" and "sectoral innovation systems" using industry data. This is nothing but the question about whether industries really define the boundaries of "technological regimes" and "sectoral innovation systems" (Leiponen & Drejer, 2007). An interesting question in this regard is whether "technological regimes" and "sectoral innovation systems" cut across industries. Prior research has assumed that firms within the same industry belong to the same technological regime. To explore whether this assumption is a valid one represents a nice avenue for further research.

A related question is whether "higher level units" apart from – or in addition to - "industries" and "sectors" can be identified that account for a substantial share of the variance in innovative activity at the firm level. Apart from "countries and "regions" that are obvious candidates in this regard, research in strategic management has suggested that certain firms "cluster" within the same industry due to similarities in strategy and firm characteristics (Peteraf & Shanley, 1997). Identifying whether sub-structures of strategic groups within industries can account for a higher share of the variance in innovative activity at the firm level represents an interesting avenue for further research in this regard as well.

But despite the high degree of heterogeneity within "industries", "sectors" or "technological regimes" noted and discussed above, structural processes and variables at the industry level still have a substantial influence on the overall level of R&D and innovation in the economy. We have seen that firms within the same industry are between 7 to 23 % similar to each other, depending on the type and nature of innovative activity. Especially for product innovation, industry effects are substantial and important. There is also a question about whether a 7 % ICC coefficient for R&D intensity is small or large. In some respects a 7 % influence of "structural variables" on firm behaviour, like R&D spending, is also a substantial impact. Small positive industry effects can, especially in the longer run, have a substantial influence on the total level of innovation and R&D in the enterprise sector and the economy.

The findings have some important implications. One important implication is that the idea that some industries are "high tech" can be rather misleading. We have documented in this paper that firms within the same industry tend to differ a lot when it comes to especially R&D, but also in relation to innovation and the managerial perception of innovation obstacles This means that firms in "low tech" industries can pursue "high tech" innovation strategies and vice versa. Policy and economic analysis that start with the assumption that some industries are more "high tech" than others can therefore lead to misleading policy implications (Von Tunzelman & Acha, 2005). What emerges from this paper is that it is important to recognise that firms are different from one another, in both "high tech" and "low tech" industries in accordance with recent evolutionary and resource based theorizing (Nelson, 1991;1995; Teece et al, 1997). Although the "industry representative" firm does not seem to exist – industry factors are still important.

We have seen that structural variables at the industry level account for up to 23 % of the variance in the firm level propensity to undertake a product innovation, and for the ability to reap the economic rents from these innovations (turnover from new innovations). Identifying the nature of these structural driving forces is an important task for future research. Policymakers can draw on such insight in order to enhance the industry factors that contribute to innovation at the firm level. A first step in such a context is arguably to conduct industry studies and analysis in order to pinpoint what a "good" sectoral innovation system is, and whether this varies across industries (Edquist, 2005). Providing new industry classifications based on firm level data maybe a way forward in this respect (Von Tunzelman & Acha, 2005; Malerba, 2005).

The results reported in this paper do also shed some empirical light over the decade's long debate in the social sciences between the relative importance of *actor* and *structure* for explaining socio-economic phenomena, such as technological change. What we have found in this paper is that the ICC values vary a lot, from around 2-23 %. This means that although "industry factors" seem to matter little when it comes to R&D and the perception of innovation obstacles at the firm level, "industry factors" have a substantial influence on the degree to which firms innovate and reap the economic rents from innovation. Although industry factors do not constrain firms much in their search behaviour, the technological regime underlying industry evolution still set some boundaries to whether firms are able to innovate, and what kinds of innovations firms are most likely to "discover" and develop.

Identifying the nature of these structural processes, and classifying industries accordingly, emerges as a key research topic (Malerba, 2005; Edquist, 2005).

Despite the "constraining" nature of technological regimes, there is still considerable room for actor and agency centred explanations of technological change. Strategy and action at the firm level are still important driving forces behind innovation and technological change as "firm effects" account for the majority of the observed variance. An important theoretical implication that emerges from this discussion is that recent evolutionary and resource based theorizing and the decade's long research on "technological regimes" and "sectoral innovation systems" complement each other. While recent evolutionary theory stress firm heterogeneity, the latter approaches stress the importance of "technological regimes" and "sectoral innovation systems" as drivers of industry evolution and technological change. As we have seen and discussed in this paper, both perspectives are valid. Together they enrich our understanding of innovation.

5. Conclusion

The main aim in this paper has been to empirically assess how important "industry" is to innovation. In order to do so we used a simple multilevel model. Our empirical results suggest that "industry factors" seem to matter little to R&D and the problems firms face in the innovation search process. These results offer empirical support to recent evolutionary and resource based theorizing where it is argued that firms have heterogeneous innovative capabilities and differ in their approach to innovation. What emerges is that agency, action and strategy at the firm level are important driving forces behind technological change.

But from the perspective of the enterprise sector and the economy as a whole, "industry effects" are still important. "Structural processes" at the industry level still yield a sometimes substantial influence on the firm level ability to develop product innovations, and on the total level of R&D and innovativeness of the economy in the longer run. This lends empirical support to the literatures on "technological regimes", "sectoral patterns of technical change", and "sectoral innovation systems".

An important theoretical implication that emerges from our results and the above discussions is that recent evolutionary and resource based theory on the one hand, and the literatures on

"technological regimes", "sectoral patterns of technical change", and "sectoral innovation systems" complement each other and enrich our understanding of innovation. Both "structural" and "actor / agency" centered explanations of technological change are valid.

The research in this paper suffers from several shortcomings that represent interesting avenues for further research. One shortcoming is that we have not used paneldata in our variance decomposition. Using such data has provided some interesting results in the "profit decomposition" literature. Another avenue for further research would be to do a variance decomposition analysis using more "narrow" industries. In this paper we have measured industries at the 2.digit NACE level. It would also be interesting to see if our results hold for different countries.

But arguably the most interesting avenue for further research is to identify the actual "structural variables" at the industry level that influence the speed and nature of technological change at the firm level. This must however be seen in relation to the strategies and actions firms implement in this regard. Quantitative research using multilevel models seem to be a way forward in this respect. Calls for such research have just started to emerge (Castellacci, 2007ab; Castellacci et al, 2005).

6. Acknowledgements

7. Appendix

In table A1 below we have decomposed the variance in binary innovation indicators using a binary linear model.

[Table A1 about here]

The Intraclass Correlation Coefficients for our three innovation indicators suggest that industry factors account for between 7 – 23 % of the total variance in firm level innovation

activities. Using a binary linear model to calculate the ICC coefficient in this context will only provide a rough estimate of the importance of "industry" to innovation. This is an acceptable procedure only when the underlying probabilities are not extreme (close to 0 or 1) (CMM, 2008)[4]. In our context, the variables in table A1 probably satisfy this assumption as 35 % of the firms in our sample have developed a "new to the firm innovation", 17 % have developed a "new to the market innovation", while 29 % have developed a process innovation.

In table A2 below we have decomposed the variance in indicators measuring turnover from new innovations for the sub-sample of product innovators.

[Table A2 about here]

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[4] This is taken from the Centre for Multilevel Modelling (CMM) website at the University of Bristol which is one of the leading research institutions when it comes to multilevel modelling.

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TABLES:

Table 1. Definition of the variables used in the analysis

New to the firm innovation	Binary indicator where the value 1 signals that the firm has introduced a product innovation new to the firm in the time period 1999-2001.
New to the market innovation	Binary indicator where the value 1 signals that the firm has introduced a product innovation new to the firm's market in the time period 1999-2001.
Process innovation	Binary indicator where the value 1 signals that the firm has introduced a new process innovation in the time period 1999-2001.
Turnover incremental innovation	% of turnover that is due to innovations new to the firm in 2001
Turnover from radical innovation	% of turnover that is due to innovations new to the firm's market in 2001
Internal R&D intensity	(Internal R&D expenditure in 2001 divided by turnover in 2001) * 100
External R&D intensity	(External R&D expenditure in 2001 divided by turnover in 2001) * 100
Economic risk	Managerial perception of economic risk as an obstacle to innovation (0 = not relevant, 3 = high importance).
Innovation cost	Managerial perception of to high innovation costs as an obstacle to innovation (0 = not relevant, 3 = high importance).
Lack of funding	Managerial perception of lack of funding as an obstacle to innovation (0 = not relevant, 3 = high importance).
Organizational rigidities	Managerial perception of economic risk as an obstacle to innovation (0 = not relevant, 3 = high importance).
Lack of qualified personnel	Managerial perception of lack of qualified personnel as an obstacle to innovation (0 = not relevant, 3 = high importance).
Lack of technological information	Managerial perception of lack of technological information as an obstacle to innovation (0 = not relevant, 3 = high importance).
Lack of market information	Managerial perception of lack of market information as an obstacle to innovation (0 = not relevant, 3 = high importance).
To strong regulation	Managerial perception of to strong regulation as an obstacle to innovation (0 = not relevant, 3 = high importance).
Lack of customer interest	Managerial perception of lack of customer interest as an obstacle to innovation (0 = not relevant, 3 = high importance).

Table 2. Decomposing the variance in perception of innovation obstacles

	High economic risk	High innovation cost	Lack of funding	Organizational rigidities
Intercept	0.91 (0.05)	0.93 (0.046)	0.71 (0.046)	0.65 (0.026)
$\Sigma \ \sigma^2_{uo}$	0.07 (0.021)	0.058 (0.018)	0.06 (0.018)	0.01 (0.005)
$\Sigma \ \sigma^2_{e}$	1.26 (0.032)	1.3 (0.032)	1.05 (0.026)	0.83 (0.02)
$ICC_{industry}$	5 %	4.3 %	5.4 %	1,2 %
N	3201	3200	3199	3202

Table 2 continued.

	Qualified personnel	Technological information	Market information	Strong regulation	Customer interest
Intercept	0.6 (0.033)	0.52 (0.03)	0.55 (0.03)	0.47 (0.03)	0.63 (0.03)
$\Sigma \ \sigma^2_{uo}$	0.03 (0.009)	0.02 (0.006)	0.024 (0.001)	0.018 (0.006)	0.02 (0.007)
$\Sigma \ \sigma^2_{e}$	0.74 (0.02)	0.55 (0.013)	0.62 (0.02)	0.61 (0.015)	0.82 (0.02)
$ICC_{industry}$	3.9 %	3.5 %	3.8 %	2.8 %	2.4 %
N	3199	3199	3199	3198	3201

Table 3. Decomposing the variance in internal and external R&D

	Internal R&D intensity	External R&D intensity
Intercept	56.87 (50.52)	35.97 (34.54)
$\Sigma\,\sigma^2_{uo}$	79879.3 (27758.7)	37655.6 (12840.8)
$\Sigma\,\sigma^2_{e}$	1055356 (24084.8)	474252.3 (10821.5)
$ICC_{industry}$	7 %	7 %
N	3899	3899

Table 4. Decomposing the variance in binary innovation indicators

	Innovation new to the firm	Innovation new to the market	Process innovation
Intercept	-0.473 (0.101)	-1.479 (0.131)	-0.754 (0.101)
$\Sigma\,\sigma^2_{uo}$	0.405 (0.108)	0.552 (0.149)	0.325 (0.09)
$\Sigma\,\sigma^2_{e}$	1	1	1
$ICC_{industry}$	11 %	14 %	9 %
Estimated scale factor	0.88 (0.02)	0.843 (0.019)	0.885 (0.02)
N	3899	3839	3899

Table 5. Decomposing the variance in innovative performance

	% turnover incremental innovation	% turnover radical innovation
Intercept	10.647 (1.554)	3.973 (0.717)
$\Sigma\,\sigma^2_{uo}$	89.08 (21.663)	17.122 (4.491)
$\Sigma\,\sigma^2_{e}$	333.126 (7.61)	133.708 (3.167)
$ICC_{industry}$	21 %	11 %
N	3873	3604

Table A1. Decomposing the variance in binary innovation indicators

	Innovation new to the firm	Innovation new to the market	Process innovation
Intercept	0.384 (0.026)	0.185 (0.019)	0.320 (0.022)
$\Sigma\,\sigma^2_{uo}$	0.022 (0.006)	0.012 (0.003)	0.015 (0.004)
$\Sigma\,\sigma^2_{e}$	0.208 (0.005)	0.127 (0.003)	0.193 (0.004)
$ICC_{industry}$	23 %	9 %	7 %
N	3899	3839	3899

Table A2. Decomposing the variance in innovative performance

	% turnover incremental innovation	% turnover radical innovation
Intercept	24,5 (2,1)	17,4 (1,5)
$\Sigma\,\sigma^2_{uo}$	144,4 (44,2)	42,5 (24,1)
$\Sigma\,\sigma^2_{e}$	543,14 (21,2)	507,5,1 (29,8)
$ICC_{industry}$	21 %	8 %
N	1364	629