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Comparing the innovation process in ?green? and ?non-green? firms: A look at barriers to innovation

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Abstract

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State-of-the-art
Although it is recognized that firms and their innovations play a key role in the ongoing structural change towards economic activity based on environmentally friendly products and processes, our understanding of environmental innovation, its driving forces, nature and effects, is still scarce (Horbach, 2008; De Marchi, 2012). Reflecting this, it is debated to what extent there is need for specific theorizing about environmental innovation and its driving forces.

Research gap
Scholars have argued that while there may be similarities between ?green? and ?non-green? innovation processes, research and theorizing about innovation in general does not cover the whole complexity of environmental innovations

(Jennings, 2000; De Marchi, 2012). Although such discussions are important, they should be illuminated by empirical evidence. Such empirical evidence is scare, reflecting the fact that environmental innovation is a recent field of research (XXX), Responding to this gap in our knowledge, the purpose of this paper is to analyse the extent to which innovation processes within ?green firms? are different from ?non-green firms?. Our approach to this issue is to focus on the barriers and hampering factors that firms may face in the innovation process. Testing the argument that environmental innovation processes are different, this paper aims to examine to what extent ?green firms? face different and stronger barriers to innovation compared to ?non-green firms?. The following research question is asked: ?To what extent do green firms face stronger barriers to innovation??

Theoretical arguments

Several studies have looked at the different barriers to innovation that firms face (Galia and Legros, 2004, Hadjimanolis, 1999, Hewitt-Dundas, 2006, Madrid-Guijarro et al., 2009). However, existing studies analyzing barriers to innovation has not looked closely at firms attempting to develop environmental innovation. An analysis of the extent to which ?green firms? face stronger barriers to innovation compared to ?non-green? firms will generate knowledge that feed directly in to the ongoing controversy about the extent to which environmental innovation needs its own theorizing (Rennings, 2000, De Marchi, 2012)

Method

The research in this paper builds upon a R&D and innovation survey that was distributed to a representative sample of Norwegian enterprises with 10 employees or more in 2009. The innovation part of the survey is the Norwegian implementation of the Community Innovation Survey (CIS) that builds on the survey methodology described in the OSLO manual (OECD, 2005). The survey was returned by 6029 firms which constitutes a response rate of 95 %.
An OLS regression analysis was conducted with different innovation barriers as the dependent variables and ?the goal to reduce environmental impact? as the main explanatory variable. Firm size, previous R&D and sales were the most important control variables.

Results

Our results show that firms in general face stronger barriers as their environmental focus increase. The strongest barriers are external barriers like lack of information on both technology and markets and different market barriers. These barriers increase with higher levels of R&D which indicate that firms with a higher proportion of qualified workers are more aware of the limitations of their knowledge on new technologies. Our results further show that stronger focus on environmental objectives correlate with increased uncertainty related to market demand. This result supports van Hemel and Cramer?s (2002) finding that firms simply cannot see that the customers will require their eco-friendly products.
Compared to ?regular? innovations that normally build on the existing knowledge of the firm, environmental innovations often change the production process of the firm and may be incompatible with the firm?s existing knowledge (del Rio et al., 2011). This may explain why lack of qualified personnel is the most important internal barrier followed by financial resources which suggest that stronger focus on reducing firms? environmental impact leads to significantly more financial barriers. Banks and external investors may be reluctant to invest in environmental R&D and innovations, both due to low returns on investment and uncertain commercial potential.

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Comparing the innovation process in "green" and "non-green" firms: A look at barriers to innovation

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Abstract

Are green innovation processes different from "non-green" innovation processes? This issue is currently debated where some authors argue that existing theorizing about innovation does not cover the complexity of "green innovation". In this paper we add to this debate by conducting an empirical analysis where barriers to innovation among "green" and "non-green firms" are compared. Using survey data from over 6000 enterprises in Norway (95 % response rate) and regression analysis, we find that firms aiming to develop and commercialize "environmental innovation" are significantly more constrained in the innovation process by both internal and external barriers to innovation, showing that green innovation processes within firms face stronger barriers to their successful development and commercialization. The results help to show that green innovation processes are qualitatively different than "non-green" innovation processes and to what extent and thus offer clear implications for the management of environmental innovation and for policy.

Keywords: Environmental innovation, financial barrier, knowledge barrier, market barrier

1. Introduction

A key challenge facing our economies and societies is the development and commercialization of environmental innovations that may be defined as "innovations that aim at reducing the negative environmental impacts caused by production methods (process innovations) and products (product innovations) (Hemmelskamp, 1997, p.178).). It should be noted that several terms have been used to describe environmental innovation in the literature: green innovation, sustainable innovation, eco-innovation and environmental innovation (Schiederig et al., 2012). A recent review study by Sciederig et al. (2012) has concluded that these terms share the same content and can "be used largely interchangeably" (p. 182). The four terms are therefore used interchangeably in this paper.

Although it is recognized that firms and their innovations play a key role in the ongoing structural change towards economic activity based on environmentally friendly products and processes, our understanding of environmental innovation, its driving forces, nature and effects, is still scarce (Horbach, 2008, De Marchi, 2012). Reflecting this, it is debated to what extent there is need for specific theorizing about environmental innovation. Scholars have argued that while there may be similarities between "green" and "non-green" innovation processes, research and theorizing about innovation in general does not cover the whole complexity of environmental innovations (see discussions in Jennings, 2000 and De Marchi, 2012) Empirical analysis of this issue is scarce however, reflecting that environmental innovation is a new field of research (Schiederig et al., 2012).

Responding to this gap in our knowledge, the purpose of this paper is to analyse the extent to which innovation processes within "green firms" are different. Our approach to this issue is to focus on the barriers and hampering factors that firms may face in the innovation process. We focus on barriers to innovation as research on this issue has been important to theorizing on innovation. Testing the argument that environmental innovation processes are different, this paper aims to examine to what extent "green firms" face different and stronger barriers to innovation compared to "non-green firms". The following research question is asked: "To what extent do green firms face stronger barriers to innovation?"

The barriers discussed in this paper originate from the Oslo Manual on the collection and interpretation of innovation data which is based on decades of research on innovation (OECD, 2005). The barriers in this manual are as such grounded in prior research and theory. Further, they have been identified by prior research as barriers that prevent firms from starting innovative activities, barriers that slow innovation activity or barriers that have a negative effect on expected results (OECD, 2005). A focus on barriers to innovation is particularly relevant within the context of green innovation. The reason is that such barriers hinder the natural flow of innovation (OECD, 2005) and the structural change towards increased sustainability. However, once the barriers to innovation are identified and their effect is understood, action can be taken to eliminate them (OECD, 2005), justifying why it is relevant to explore what barriers to innovation green firms face and the extent to which these barriers are stronger within green firms.

Although the development and commercialization of new technology is difficult in general (Czarnitzki and Hottenrott, 2011), this may be particularly so in the context of environmental innovation due to increased risk and more uncertain market demand (Rennings and Rammer, 2011, van Hemel and Cramer, 2002). Our knowledge about whether and to what extent the difficulties surrounding the development and commercialization of environmental innovation are greater than the development and commercialization of other technologies is limited. This study's primary contribution is thus to explore whether and to what extent green innovation face stronger barriers to innovation when compared to non-green firms.

A related and second contribution from this paper to the literature is that our research sheds empirical light over the debate in the literature about the extent to which environmental innovation requires specific theorizing by focusing on barriers to innovation and to what extent these are stronger and different in green firms. A third contribution that is interesting in its own right is that our research provides insight into factors that constrain the ability of green firms to develop new environmental innovations that our societies need to adopt sooner rather than later to reduce environmental waste and pollutions, to save energy etc.. While some studies on the driving forces behind environmental innovations have recently been conducted (Brunnermeier and Cohen, 2003, Hemmelskamp, 1997, del Brio and Junquera, 2003, Horbach, 2008) classifying them as either driven by market pull, technology push or by regulatory-driven factors (Rennings and Rammer, 2011), few studies have looked more closely into the inhibiting factors to environmental innovation and what these inhibiting factors actually are (Moors et al., 2005, van Hemel and Cramer, 2002).

A forth contribution is that our research is based on empirical analysis of environmental innovation and inhibiting factors using a large scale firm database. There is currently limited knowledge about factors influencing the successful management and actual market commercialization of environmental innovations and to what extent this is different compared to other innovations, especially knowledge based on representative large-scale quantitative studies seen from the perspective of the firm (Balachandra et al., 2010)

The paper is organized as follows. The next section discusses to what extent environmental innovation needs its own theorizing, including our approach to examining this issue by focusing on barriers to environmental innovation within green and non-green firms. Section 3 presents the method and the data used to answer our research question. The analysis and its results are discussed in section 4, while section 5 concludes.

2. Conceptual background

Green innovation and policies that foster increased sustainability is high on the policy agenda in most countries. Reflecting this, there is an increasing need to understand the nature of environmental innovation, its antecedents and effects. A current debate in the literature on environmental innovation is to what extent environmental innovation is a type of innovative activity that needs its own theorizing and approaches (De Marchi, 2012, Rennings, 2000). It has been argued that although theorising about environmental innovation may benefit from theorizing about innovation in general, theorizing about innovation in general may not cover the whole complexity of the nature of environmental innovation, and it's driving forces (De Marchi, 2012). A highly debated issue is thus to what extent existing theories from studies of innovation in general can be transferred to the context of environmental innovation (Rennings, 2000).

The prime mover for innovative activity has traditionally been classified into two broad categories; "demand-pull" and "technology-push" theories. Demand-pull theories emphasize that changes in market conditions create opportunities for firms to invest in innovation to satisfy unmet needs (Nemet, 2009), whereas technology-push theories focus on science and technology and the role they play in developing technological innovations and adapting to the changing characteristics of the industry structure (Di Stefano et al., 2012). These categories have been much debated during the last three decades concluding that neither a pure demand-pull nor a technology-push perspective is ideal to explain the innovation process. The first perspective ignores technological capabilities, whereas the latter fails to account for market conditions (Nemet, 2009). A successful innovation shows the ability to connect a technical opportunity to a market opportunity (Nemet, 2009). The technology push factors are generally important in the early phases of product development, whereas demand factors become more important during the diffusion phase (Horbach, 2008).

Regarding environmental innovations, most environmental problems represent negative external effects which do not give any clear economic incentives to develop (Horbach, 2008). The literature on environmental innovation therefore discusses the role of regulation as a

determinant for innovation. Rennings and Rammer (2011) presents four channels through which environmental regulations can stimulate firm innovation activities. First, environmental regulations encourage the development of product innovations, especially when the state of the art is not sufficient to comply with the new regulations. Secondly, environmental regulation facilitates the development of new products when firms are faced with new requirements regarding the use and non-use of certain materials, dangerous substances or other product properties such as recyclability, higher energy efficiency or a reduction in air, wastewater and noise emissions. Thirdly, environmental regulations may stimulate investment activities which go beyond merely complying with new regulations and rather aim at developing improved procedures and quality improvement in a broader sense. Finally, environmental regulations facilitate new services which are aimed at counseling firms in environmental issues such as environmental certifications and the assessment of environmental policies. The importance of regulations in the environmental innovation process calls for an extension of the technology push/ demand pull theories when it comes to explain environmental innovations. Cleff and Rennings (1999) propose an extended model to illustrate the determinants of environmental innovation as shown in figure 1.

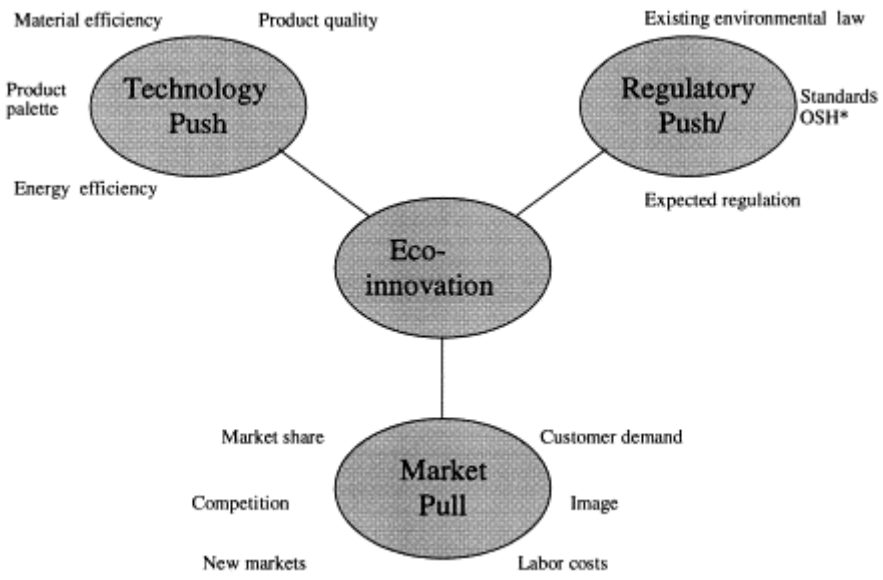

Figure 1: Determinants of environmental innovation (Cleff and Rennings, 1999)

Firms have different motivations for eco-innovating. Frondel et al. (2007) distinguishes between two different types of environmental innovation; cleaner production and end-of-pipe technologies. Cleaner production reduces resource use and/or pollution at the source by substituting or modifying less clean technologies, whereas end-of-pipe technologies only curb pollution by implementing add-on measures (Frondel et al., 2007). Firms undertaking end-of-pipe solutions do so because they have to fulfill environmental protection tasks. Environmental innovations developed by such firms are strongly influenced by regulatory push factors. Firms aiming at fixing the source of their environmental problems are more

likely to expect positive effects of their environmental innovations in the sense that they can reduce the costs associated with environmental regulation, increase their competitiveness and create new markets for environmentally desirable products and processes (Frondel et al., 2007). Environmental product innovations available in the market are mostly influenced by the strategic market behavior of firms, where firms try to comply with certain ecological standards demanded by market-related groups such as customers, consumer associations and investors (Hemmelskamp, 1997, Cleff and Rennings, 1999). The positive environmental effects of cleaner technologies are well documented, but unfortunately there still seems to be problems related to scaling up environmental products from niche markets to mass markets (Frondel et al., 2007) and thereby gaining profits by being environmental.

Our approach to the discussion on environmental innovation is to analyze to what extent "green firms" face stronger barriers to innovation compared to non-green firms. Several studies have looked at the different barriers to innovation that firms face (Hewitt-Dundas, 2006, Hadjimanolis, 1999, Freel, 2000). However, existing studies analyzing barriers to innovation has not looked closely at firms attempting to develop environmental innovation. If we looked more closely at such firms, what would we see? Would we find that "green firms" face stronger barriers to innovation as some studies and theorists propose (e.g. De Marchi, 2012)? Or would we find that firms in the process of developing "green innovation" face similar hampering factors as "non-green" firms. No matter what the answer is, an analysis of the extent to which "green firms" face stronger barriers to innovation compared to "non-green" firms will generate knowledge that feed directly in to the ongoing controversy about the extent to which environmental innovation needs its own theorizing (Rennings, 2000, De Marchi, 2012) and have the potential to inform policymakers and practitioners about the extent to which existing policies, derived from studies of innovation in general, can be used to facilitate structural change towards increased sustainability based on green innovation.

2.2 Barriers to innovation

There have been several studies of barriers to innovation (Freel, 2000, Galia and Legros, 2004, Hadjimanolis, 1999, Hewitt-Dundas, 2006, Madrid-Guijarro et al., 2009). These studies contribute to our understanding of barriers and how we can create an environment that supports innovation (Hadjimanolis, 1999). Several studies have discussed the barriers proposed in the Oslo Manual; financial barriers (Freel, 2000, Hewitt-Dundas, 2006, Madrid-Guijarro et al., 2009), lack of qualified personnel (Galia and Legros, 2004, Hadjimanolis, 1999), lack on information on technology and markets (Galia and Legros, 2004, Hewitt-Dundas, 2006), lack of partners (Hewitt-Dundas, 2006, Freel, 2000, Hadjimanolis, 1999) and uncertain market demand (van Hemel and Cramer, 2002). These barriers can be discussed in terms of internal barriers (finance and personnel) and external barriers (information, partners and demand) (Madrid-Guijarro et al., 2009)

2.2.1 Internal barriers

The high cost of innovation is an influential internal barrier to innovation, particularly for smaller firms (Madrid-Guijarro et al., 2009). R&D and innovation projects are to a great extent financed by internal sources (Himmelberg and Petersen, 1994, Czarnitzki and Hottenrott, 2011). This situation could be a result of a voluntary firm strategy or rather the result of financial constraints (Ughetto, 2008). Young companies with little profit accumulation will not have the same opportunities to finance their R&D projects as older firms with more internal resources (Czarnitzki and Hottenrott, 2011). Galia and Legros' (2004) study of French manufacturing firms showed that the cancellation of innovation projects was due to economic constraints, and not technological or organizational impediments. It should however be noted that Galia & Legros' (2004) analysis was constrained to already innovative firms. Their analysis thus suggests that the likelihood that already innovative firms will cancel or postpone their innovation projects may increase with the presence of stronger resource constraints, and especially financial constraints.

Innovations that require large up-front investments or have long pay-back periods, like many radical environmental innovations, are problematic for many firms. These kind of innovations may be beyond the capacity of many firms which are not able to invest neither the capital required, nor the time or the human resources (Matus et al., 2012). Accessing capital may be difficult due to the low collateral value of R&D investments (Czarnitzki and Hottenrott, 2011) combined with a lack of collateral or physical assets to act as security for bank loans will act as a strong financial barrier for innovation, especially for small firms with limited resources (Hadjimanolis, 1999, Freel, 2000). An additional barrier related to environmental innovations is the difficulty of calculating the economic benefits from such innovations (Matus et al., 2012). The development of environmental innovations and especially radical technological changes in traditional industries such as the metals industry, require enormous capital investments and long-term decision making and may therefore be associated with increased risk and uncertainty than the development of "general innovations" (Moors et al., 2005). Large firms and firms that belong to a concern spend more on R&D than individually owned firms (Shefer and Frenkel, 2005). These firms are more able to secure the necessary funding for R&D and the risk of investing in environmental innovations is therefore smaller for larger firms. This is supported by Hewitt-Dundas (2006) which found a strong relationship between the lack of finance to innovation and the risk associated with innovation. She also found that the risk of innovation was strongly correlated with the rate of return from innovation. Hence, firms investing in risky environmental innovations should have the financial resources to make investments for the future even if they cannot see that the investments will give immediate competitive advantages or return on investment.

Xie et al's. (2010) study of Chinese manufacturing SMEs found that the lack of technical experts was the most important barrier for SMEs to engage in innovation activities. This is supported by both Frenkel (2003) and Hadjimanolis (1999) who offered some mainly descriptive evidence which suggests that the lack of skilled labour are among the most important barriers to innovation for many small and medium sized firms. Small firms are disadvantageous in the market for skilled labor because they are often unable to match the wage rates, career development opportunities or job security available within large firms

(Bosworth, 1989). Skilled workers are important for the innovation learning process and more innovating firms often face more problems than less innovating firms (Galia and Legros, 2004). An explanation to this could be that firms with a higher proportion of qualified workers are more aware of the limitations of their knowledge on new technologies and may therefore report this as a barrier whereas firms without this level of qualification may not be aware of their own limitations (Hewitt-Dundas, 2006). In other words; the perception of obstacles increases as more R&D is conducted (Mohnen, 2002).

2.2.2. External barriers

Small firms are less likely to undertake innovation than larger firms (Hewitt-Dundas, 2006) and face higher resource and capability constraints to innovation than larger firms. Some constraints will weaken over time, but some barriers like lack of partners seems to persist over time and has a negative impact on the ability of small firms to undertake innovation. Firms with weak external partnerships will miss out on the benefits from such partnerships like more innovation activity, reducing risk and access to complementary assets and resources (Hewitt-Dundas, 2006). De Marchi's (2012) study of Spanish Manufacturing firms showed that partners and cooperation is more important to the introduction of environmental innovations than to the introduction of non-environmental innovations. External innovation partnerships may therefore be important to stimulate and facilitate innovation, and especially environmental innovations. This is supported by Freel's (2000) study of innovating and non-innovating small and medium sized firms (SMEs) in the UK manufacturing sector, where he found that a lack of trust and R&D partners posed a clear barrier to innovation cooperation for small firms. However, there are studies (Madrid-Guijarro et al., 2009) which found that firms which faced stronger external barriers (proxied by several items such as lack of market information, lack of technological information as well as lack of external cooperation partner) were more innovative in terms of both product and process innovation.

Examples of external partners are customers, suppliers, competitors, universities and other research institutions. Xie et al. (2010) found that the most important external relationships for SMEs were vertical cooperation customers and suppliers which played a more important role in the innovation process than horizontal cooperation with universities and research institutions.

A study by van Hemel and Cramer (2002) of eco-design in Dutch SMEs found that the market for environmental products act as a barrier for innovation. The firms simply cannot see that the customers will require their eco-friendly products. The same study also found that many small firms did not regard eco-design as their responsibility and that they were not influential enough to bring about any changes without the help of larger firms. Marketing skills also act as a barrier to innovation in Freel's study of manufacturing SMEs in West Midland, England. He found that most firms were aware of their lack of marketing expertise themselves.

3. Method, data and variables

In this section we discuss the methodology, data and variables used in the analysis. Ordinary least squares (OLS) regression will be used to analyse the relationship between (latent measures of) innovation obstacles and firms attempting to develop environmental innovations.

3.1 Data

The research in this paper builds upon a R&D and innovation survey that was distributed to a representative sample of Norwegian enterprises with 10 employees or more in 2009. The innovation part of the survey is the Norwegian implementation of the Community Innovation Survey (CIS) that builds on the survey methodology described in the OSLO manual (OECD, 2005). The survey was directed to firms in most industries within both the manufacturing and service sector.

The survey was returned by 6029 firms which constitutes a response rate of 95 %. The survey was administered by Statistics Norway and the authors of this paper got access to the raw data once the data collection had finished.

3.2 Variables

3.2.1 Dependent variables

A predefined set of survey questions referring to innovation obstacles as perceived by the responding firm managers were included in the survey. These questions were directed to the firm management and capture the management's perception of the barriers to innovation that his/her firm is facing.

The following general question was asked: "If your enterprise experienced any hampering factors during the period 2006-2008, please grade the importance of the relevant factors". The responding manager could tick 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 (HMAR)", "difficult to find cooperation partners for innovation (HPAR)", "market dominated by established incumbents (HDOM)" "uncertain demand after new goods and services (HDAM)", "no need due to prior innovations (HPRIOR)" and "no need due to lack of demand (HMAR)".

3.2.2 Main explanatory variable

Responding firms were also asked to indicate the objectives and main goals underlying innovative activity in the time span 2006-2008. One of the objectives that firms could tick, on

a scale from 0 (not relevant) to 3 (very important), was "to reduce environmental impacts". For the purpose of this study, this particular question in the CIS survey measures firms attempt to develop an environmental innovation. The attempt and objective to develop an environmental innovation is the main explanatory variable in this paper. This study will thus test whether and to what extent firms with the objective to develop an environmental innovation will face higher obstacles to innovation.

It needs to be noted that due to the cross-sectional nature of our research design and the overlap in time between the main independent and dependent variables, the relationship between these variables can only be assumed. Hence, we assume that the innovation process starts with an "objective" to develop an environmental innovation and that this objective has an influence on the types and strength of the obstacles to innovation that the firm will face, and not vice versa.

3.2.3 Control variables

Larger firms may have access to a superior resource base due to their size. Many studies have thus argued that larger firms are more innovative than smaller firms (See Cohen; 1995; 2003 for surveys). Due to this we will control for firm size in the regression. Firm size is measured by the number of employees and used in log form. We will also control for differences among the firms in our analysis in terms of financial resources. As a proxy for financial resources, we will add sales in 2008 as a control variable (used in log form).

In order to control for differences among firms in relation to their technological capabilities we add R&D as control variables defined as the log of expenditure on R&D. This is an important control variable as prior research on innovation obstacles has found that firms conducting R&D face more obstacles to innovation compared to non-R&D firms (Hewitt-Dundas, 2006).

Past research has shown that industries differ in terms of opportunities and barriers to innovation. In order to control for such industry heterogeneity we include industrial sector industry dummies in the analysis as control variables (measured at the 2.digit NACE level).

Ending this section it is important to underline that all firms were asked to answer all questions in the CIS survey that are used in this study. However, due to item non-response about 300 firms drop out from the OLS regressions.

4. Analysis

4.1 Findings

In the table below we have displayed the results from the OLS regression where various types of innovation obstacles are the dependent variables and the attempt to develop an

"environmental innovation" is the main explanatory variable. Standardized regression coefficients (BETA) are reported.

Table 1. Examining the relationship between "attempt to develop environmental innovations" and "obstacles to innovation" – standardized regression coefficients.

Variables	Innovation cost (HCOS)	Lack of internal finance (HFENT)	Lack of external finance (HFOUT)	Lack of qualified personnel (HPER)	Lack of info. on technology (HTEC)	Lack of info. on markets (HMAR)
Environmental innovation	.298***	.294***	.288***	.350***	.359***	.343***
Firm size (log)	-.042**	-.015	-.015	-.005	-.010	-.004
R&D (log)	.301***	.287***	.274***	.252***	.168***	.193***
Sales (log)	-.016	-.068***	-.098***	-.033*	-.016	-.049*
Industry controls	Included	Included	Included	Included	Included	Included
R^2	27 %	26 %	25 %	25 %	22 %	22 %
N	5694	5693	5687	5696	5693	5691

Variables	Cooperation partners (HPAR)	Dominated by established firm (HDOM)	Uncertain demand (HDAM)	Prior innovations (HPRIOR)	Lack of demand (HMAR)
Environmental innovation	.324***	.341***	.332***	.305***	.313***
Firm size (log)	-.017	-.054***	-.009	.017	.002
R&D (log)	.189***	.145***	.204***	.096***	.126***
Sales (log)	-.054***	-.030	-.033	.010	.015
Industry controls	Included	Included	Included	Included	Included
R^2	19 %	18 %	22 %	15 %	16 %
N	5691	5688	5691	5684	5684

*** (**,*) Significant at 1% (5%, 10%)

It can be seen from Table 1 that there is a positive significant correlation between the objective to develop environmental innovations and the importance of different hampering factors. "Environmental innovation" has a medium-strong positive relationship with the dependent variables: BETA-value ranges from .288 to .359. All independent variables, including "environmental innovation", are significantly related to the dependent variables at the 1 %-level. Explained variance is rather good in all models, especially when one considers the relatively low level of explanatory variables. R^2 ranges between 15-27 %.

4.2 Discussion

4.2.1 Internal barriers

Compared to "regular" innovations that normally build on the existing knowledge of the firm, environmental innovations often change the production process of the firm and may be incompatible with the firm's existing knowledge (del Rio et al., 2011). This may explain why lack of qualified personnel is the most important internal barrier. Data on financial resources; "innovation costs too high (HCOS)", "lack of finance within the enterprise (HFENT)" and "lack of appropriate sources of finance from outside the enterprise (HFOUT)" suggest that stronger focus on reducing firms' environmental impact leads to significantly more financial barriers. This relationship could be explained by the level of risk and uncertainty associated with environmental innovations (Moors et al., 2005). Banks and external investors may be reluctant to invest in environmental R&D and innovations, both due to low returns on investment and uncertain commercial potential. The motivation behind the firms' focus on reducing its environmental impact will play an important role in financing environmental R&D and innovations. Innovations motivated by market pull will have much more commercial potential than innovations motivated by regulatory push/pull.

4.2.2 External barriers

We found evidence that lack of information on technology (HTEC) are among the most important external barriers to environmental innovations. Firms have different abilities to access and utilize technological information and lack of relevant information works as a barrier against environmental innovations. Our analysis also shows that the level of R&D is linked to the perceived barriers for innovation. This supports Hewitt-Dundas' (2006) finding that firms with a higher proportion of qualified workers are more aware of the limitations of their knowledge on new technologies and may therefore report this as a barrier whereas firms without this level of qualification may not be aware of their own limitations.

An important barrier for environmental innovations is the perception that the market is dominated by established firms (HDOM). This result can be linked to Nehrt's (1996) and Russo and Fouts' (1997) studies which emphasize the first-mover advantage in emerging "environmental" markets. Firms entering the market at a later stage will face more barriers to entry than the early-movers. Another uncertain factor related to environmental innovations is the market demand. Our results show that stronger focus on environmental objectives correlate with increased uncertainty related to market demand (HDAM, HPRIOR). This result supports Frondel's (2007) finding that there are problems related to scaling up environmental products from niche markets to mass markets.

5. Conclusion and Implications

Our study shows that firms which focus their R&D efforts on improving their environmental performance face more barriers as their environmental focus increase. Both limited access to financial and knowledge resources as well as an uncertain market demand act as significant barriers for environmental innovations. These findings have important implications for the development of policies to help firms engaged in the development of environmental innovations.

When the cost associated with environmental innovations is considered too high and firms experience trouble attracting investors, direct and indirect governmental financial measures could be important elements in order to overcome the financial barriers. The establishment of financial measures exclusively for environmental R&D might be an important incentive for the development of more environmental innovations. Dedicated schemes directed towards environmental friendly R&D could support both existing environmental friendly firms in their development of new innovations, but it will also encourage other more "traditional" firms to include environmental aspects in their R&D. In addition to an "environmental R&D-fund" the government should also include environmental considerations in their overall R&D-funding which will set stricter demands to environmental aspects of firms' R&D. The government could also support environmental innovations more indirectly by introducing front and back end tax incentives. The front end incentives could be related to tax reliefs on invested R&D. Back end incentives could be related to reduced capital gains tax for firms that develop, introduce and sell environmental friendly products and services.

However it is not enough to take down the financial barriers for the development of environmental innovations as our research shows that many firms are unable to provide the necessary knowledge resources for environmental innovation projects. Facilitating partnerships or strategic alliances might help firms overcoming these barriers by creating economies of scale, mitigate risk and leverage resources together. To form such alliances, the individual firms, industry organizations, universities, R&D-institutes and the government all play important roles. The individual firms should realize that they have to share their information to be able to gain more information from partners, and industry organizations can be an important facilitator for cooperation both between firms within an industry and between firms and organizations providing external R&D such as universities and R&D institutes. To do all this firms are dependent on governmental policies and legislation, facilitating and allowing these kinds of partnerships.

An uncertain market demand for environmental innovations can be influenced by environmental regulations. Although more and more scientists, politicians, firms and customers focus on environmental issues, environmental regulations will remain the most important tool to change the market demand in the short run.

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