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

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Abstract

Are environmental innovation processes different from non-environmental innovation processes? This issue is currently debated where some authors argue that existing theorizing about innovation does not cover the whole complexity of environmental innovation. In this paper we add to this debate by conducting an empirical analysis where barriers to innovation are compared among environmental and non-environmental firms, and among regulation-driven and market-driven environmental firms. 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 innovations are significantly more constrained in their innovation process, and more specifically, we find that regulation-driven environmental firms are more constrained than market-driven firms by both internal and external barriers to innovation. The results help to show that environmental innovation processes are qualitatively different than non-environmental innovation processes and that there are also differences within environmental firms.

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Keywords: Environmental innovation, regulation, market demand

1. Introduction

A key challenge facing our economies and societies is the development and commercialization of environmental innovations that may be defined as . 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 Schiederig et al. (2012) has concluded that these terms share the same content and can *"be used largely interchangeably"* (p. 182).

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 "environmental" and "non-environmental" 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 "environmental 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. The barriers used in this study are grounded in prior research and theory (Keupp and Gassmann, D'Este et al., 2012), and have been identified 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 environmental innovation. The reason is that such barriers hinder the natural flow of innovation (OECD, 2005) and may hinder the structural change towards increased sustainability as proposed in this paper. 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 environmental firms face and the extent to which these barriers are stronger within environmental firms.

Testing the argument that environmental innovation processes are different, this paper aims to examine to what extent "environmental firms" face different and stronger barriers to innovation compared to "non-environmental firms". The following research question is asked: "Do environmental firms face stronger barriers to innovation?" Our research question is elaborated into two testable hypotheses which take the heterogeneity of environmental firms into account.

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 environmental innovation face stronger barriers to innovation when compared to non-environmental 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 in environmental firms. A third contribution is that our research adds to the environmental innovation literature by providing new insight into the differences between regulation driven and market driven environmental innovations by comparing the barriers to innovation in firms with high environmental and high regulatory objectives against firms with high environmental but low regulatory objectives. 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 environmental and non-environmental 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 theorizing about environmental innovation may benefit from theorizing about innovation in general, however, 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), and more specifically, do environmental firms face the same barriers to innovation as non-environmental firms?

Why a focus on barriers to innovation? There are several approaches to innovation research, and one approach is to study the nature, origin and importance of different barriers to innovations. Policymakers, scholars and practitioners have for a long time been interested in barriers that constrain firms' ability to innovate. For instance, the Community Innovation Survey (CIS), which builds on decades of research and theorizing on innovation, collects data about the prevalence and strength of barriers to innovation in the business sectors in the entire EU (+ Norway and Iceland) every second year. Knowledge about barriers that constrain firms' ability to innovate is important for several reasons. Barriers hinder the natural flow of innovation and slow the pace of structural change, such as the transition towards sustainable existence. However, once the barriers to innovation are identified and their effect is understood, action can be taken to eliminate them (OECD, 2005). Studies on barriers to innovations contribute to our understanding on how an environment that supports innovation can be created (Madrid-Guijarro et al., 2009).

Several types of barriers to innovation exist. Prior research has focused on 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 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 thus an ideal setting to examine the issue of whether or not green innovation processes are different compared to non-green innovation processes. Such an analysis will help answer the question of whether or not green firms face stricter hampering factors in the innovation process, and if so what these hampering factors are. Further, such an analysis has the potential to offer clear policy advice. If green firms face stricter barriers to innovation, policies may need to be formulated to address these if our societies are to succeed with the structural change towards increase sustainable industrial activities.

2.1 Environmental innovation and barriers to innovation

The prime mover for innovative activity has traditionally been classified into two broad categories; "demand-pull" and "technology-push" theories. 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, rather that most innovations are a combination of both (Nemet, 2009). Environmental innovations are, however, a special type of innovative activity where regulatory push/pull effect is an essential motivation (Rennings and Rammer, 2011) and seek to reduce negative external environmental effects of economic and industrial activities, such as pollution and waste. Thus, it is argued that in the case of environmental innovation technology push and market pull factors alone do

not seem to be strong enough, rather regulations and standards, often imposed on firms by policymakers, is considered to be the prime determinant of environmental innovation and regulations are significantly more important for environmental innovations than for other kinds of innovations (Horbach et al., 2012). There are several channels through which regulations stimulate environmental innovations. First, regulations stimulate the technological development if the state of the art is not sufficient to comply with the existing regulations (Rennings and Rammer, 2011). Secondly, regulations may stimulate market demand and giving environmental benefits a value in the market by facilitating for the development of new products through requirements regarding the use and non-use of certain materials, dangerous substances and other product properties (Rennings and Rammer, 2011). No other actor than the government can do this on large and systematically scale (Kemp and Oltra, 2011).

When regulation, and not expected demand or advances in technology, is the prime determinant of innovation, firms may face stricter barriers to innovation, which could result in a higher expected lack of demand and lack of market information as impediments to innovation. The reason is that environmental innovation does not seek to address a demand in the traditional sense, rather address negative external effects of production (Horbach, 2008). Hence, there may be no customers to interact with and collect information from which may guide the innovation process. The entire market may even by non-existing, which could make lack of demand a particular higher barrier to innovation for regulation driven green firms (van Hemel and Cramer, 2002). Structures within the market, such as market concentration and large firms with monopoly power, may also inhibit the commercialization of new environmental technologies. The reason is that large firms which dominate an industry have few incentives to embrace a new technological paradigm which environmental innovation may represent.

Further, the development and commercialization of environmental technologies will often go beyond firms` core competences. Thus, green firms will often have to search for completely new knowledge and solutions to succeed with the commercialization of environmental technologies. Access to technological knowledge may thus pose a particularly important barrier for green firms.

When new technological knowledge and information is not easily available in-house or in the industry, firms may often need to source such knowledge from external actors and/or develop such knowledge together with other firms and partners in R&D alliances. Environmental innovations will therefore rely more on external knowledge sources and cooperation compared to other innovations (Horbach et al., 2012, De Marchi, 2012). This dependency on external partners might cause problems for environmental firms in finding the right partners and establishing cooperative alliances. As a result of this, environmental firms might experience more difficulties in their innovation processes than other firms. The following hypothesis reflects this:

Hypothesis 1: Firms with higher green innovation goals face stronger barriers to innovation.

The assumption that regulation is the key determinant that differentiates environmental innovations from general innovations is much discussed within the environmental innovation literature, giving less attention to non-regulatory environmental innovations. Firms pursuing environmental innovations may not be a homogenous group and the discussion of whether there are differences between environmental and non-environmental firms should be extended to include a more thorough discussion of the potential differences among environmental firms. The strong focus on innovations motivated by regulations has left little space for

discussions about the extent to which environmental firms are influenced by market conditions, and if there are significant differences between different types of green firms.

One obvious difference between market-driven and regulation-driven environmental innovations is the demand side. Market-driven environmental firms are depending on the environmental consciousness of the consumers and their willingness to choose environmental solutions. These firms address a demand from the market, and although there still seems to be problems related to scaling up environmental products from niche markets to mass markets (Frondel et al., 2007), these firms have greater market opportunities than regulation-driven firms, particularly in circumstances where customers are willing to switch due to environmental performance (Yalabik and Fairchild, 2011). This makes information on markets and customer demand a key to successful innovation. By contrast, regulation-driven firms are "forced" to innovate to address negative external effects of their production, from which there is no clear economic benefits (Horbach, 2008). Further, there might exist many environmental technological opportunities, but with a limited market demand firms may not be motivated to pursue these opportunities. However, environmental regulations will push some firms to explore new environmental technologies, but the effect of regulation on firms can differ considerably. A recent study has shown that regulations have most impact on investments in end-of-pipe technologies, which have the lowest environmental and technological impact and, at the same time, they encourage investments in environmental R&D, which has the highest environmental and technological impact (Demirel and Kesidou, 2011). These results imply that regulations can both stimulate short-term solutions, such as simple process innovations, as well as setting strict technological standards and thereby play an important role in the long run by encouraging innovation through environmental R&D (Demirel and Kesidou, 2011).

However, regulation-driven environmental innovations are often associated with new technologies and high innovative intensity which require new knowledge and equipment. This may result in higher obstacles to innovation, such as higher innovation costs (Horbach et al., 2012). Environmental innovations, in particular those that are regulation driven, may therefore go 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).The following hypothesis reflects this:

Hypothesis 2: Regulation driven green firms face stronger barriers to innovation.

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 (HINF)", "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". Previous CIS surveys have provided some insights into environmental innovations, but unfortunately the motive to "reduce environmental impacts" has been merged with health and safety motives (Veugelers, 2012). This study will therefore more explicitly reflect an environmental motive compared to previous CIS studies using the merged measure. This paper starts with an analysis where the attempt and objective to develop an environmental innovation is the main explanatory variable. 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. The analysis is extended to include the distinction between regulatory driven and market driven environmental firms. We computed two new binary explanatory variables, the first measuring firms with high environmental objectives and high regulatory objectives, and the latter measuring firms with high environmental objectives but low regulatory objectives. This will test whether there are differences between regulatory driven and market driven environmental firms in their perception of innovation obstacles.

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).

The differences in the demand for environmental innovations can be linked to the type of innovation and we therefore control for product and process innovation. Environmental process innovations generally confers little additional benefit for the customer and therefore receives comparatively little reward form the market, while product innovations brings added benefits to the customer (Cleff and Rennings, 1999), and can be more of interest for market driven firms.

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.

Table 1 show the descriptive statistics and table 2 shows the correlations between the variables in our regression analysis.

Table 1. Descriptive statistics

Variables	N	Mean	Std.dev.	Min.	Max
HCOS	5856	.92	1.070	0	3
HFENT	5856	.83	1.021	0	3
HFOUT	5849	.75	.997	0	3
HPER	5859	.74	.913	0	3
HTEC	5859	.59	.739	0	3
HINF	5858	.62	.776	0	3
HPAR	5856	.59	.802	0	3
HDOM	5853	.67	.868	0	3
HDAM	5853	.79	.940	0	3
HPRIOR	5845	.53	.744	0	3
HMAR	5843	.58	.798	0	3
EBEN	5723	1.12	1.17	0	3
ln_fou	6029	1.98	3.52	0	13.72
ln_emp	6029	3.55	1.22	1.79	9.84
ln_oms	6029	10.90	1.85	0	20.19
only_env	6029	.0156	.12	0	1
reg_env	6029	.3427	.47	0	1
Produkt_binær	6029	.2466	.43	0	1
Prosess_binær	6029	.2055	.40	0	1

Table 2. Correlation matrix

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.HCOS	1																		
2.HFENT	.80	1																	
3.HFOUT	.75	.83	1																
4.HPER	.64	.63	.62	1															
5.HTEC	.66	.64	.64	.71	1														
6.HINF	.65	.64	.63	.69	.82	1													
7.HPAR	.64	.64	.66	.64	.72	.73	1												
8.HDOM	.61	.59	.59	.60	.64	.68	.67	1											
9.HDAM	.66	.64	.62	.62	.65	.70	.66	.73	1										
10.HPRIOR	.51	.48	.47	.50	.57	.57	.54	.57	.58	1									
11.HMAR	.55	.54	.52	.53	.59	.62	.59	.62	.70	.71	1								
12.EBEN	.37	.36	.35	.40	.41	.39	.37	.38	.38	.34	.35	1							
13.ln_fou	.39	.38	.36	.35	.27	.29	.27	.23	.30	.19	.22	.23	1						
14.ln_emp	.02	.00	-.03	.04	.03	.01	-.01	-.03	.02	.06	.05	.08	.21	1					
15.ln_oms	.01	-.03	-.06	.02	.02	-.00	-.02	-.02	.01	.05	.05	.09	.15	.78	1				
16.only_env	.06	.07	.08	.04	.04	.02	.04	.03	.03	.01	.02	.21	.13	.04	.02	1			
17.reg_env	.28	.27	.27	.33	.34	.33	.30	.32	.31	.28	.29	.84	.11	.06	.08	-.09	1		
18.Produkt_binær	.39	.36	.33	.32	.25	.30	.25	.25	.33	.20	.24	.22	.56	.08	.07	.05	.15	1	
19.Prosess_binær	.31	.28	.24	.27	.24	.23	.23	.20	.25	.18	.19	.24	.39	.08	.06	.08	.15	.47	1

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 (HINF)
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	Uncertain demand	Prior innovations	Lack of demand

		established firm (HDOM)	(HDAM)	(HPRIOR)	(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 %.

Table 2. Relationship between environmental or regulatory driven innovations and different obstacles to innovations.

Variables	Innovation cost	Lack of internal	Lack of external	Lack of qualified	Lack of info. on	Lack of info. on

	(HCOS)	finance (HFENT)	finance (HFOUT)	personnel (HPER)	technology (HTEC)	markets (HINF)
Environmental driven	.034***	.052***	.057***	.034***	.039***	.022*
Regulatory driven	.246***	.237***	.239***	.303***	.310***	.308***
Firm size (log)	-.042**	-.015	-.014	-.004	-.010	-003
R&D (log)	.332***	.314***	.299***	.287***	.205***	.228***
Sales (log)	-.011	-.063***	-.091***	-.029	-.011	-.044**
Industry controls	Included	Included	Included	Included	Included	Included
R^2	23,8 %	22,9 %	21,9 %	22,5 %	18,5 %	19,4 %
N	5855	5855	5848	5858	5858	5857

Variables	Cooperation partners (HPAR)	Dominated by established firm (HDOM)	Uncertain demand (HDAM)	Prior innovations (HPRIOR)	Lack of demand (HMAR)
Environmental driven	.038***	.032***	.028**	.016	.024*
Regulatory driven	.277***	.296***	.282***	.261***	.267***
Firm size (log)	-.017	-.051**	-.005	.021	.004
R&D (log)	.220***	.179***	.239***	.128***	.157***
Sales (log)	-.048**	-.026	-.031	.011	.017
Industry controls	Included	Included	Included	Included	Included
R^2	16,4 %	15,5 %	19,1 %	12,1 %	13,1 %

N	5855	5852	5852	5844	5842

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

Table 2 shows that there is a positive relationship between the aim to be environmental, and at the same time comply with regulations, and all the barriers in our model. We also observe that this is the case for the firms with only environmental objectives in relationship to all obstacles except the barrier due to prior innovations (HPRIOR). Although both of our main explanatory variables have (mostly) significant positive relationships with the dependent variables, the regulatory driven variable has a stronger relationship with BETA-values ranging from .237 to .310 than the environmental driven variable which has significant BETA-values from .022 to .057.

4.2 Discussion and conclusion

Up until now, the most discussed difference between environmental and non-environmental innovations has been the importance of regulations in motivating new green innovations. There are, however, few discussions on the impact of this difference and if there are differences within environmental firms. This paper contributes to the literature by exploring whether and to what extent environmental firms faces stronger barriers to innovation when compared to non-environmental firms, and further if there are differences between firms motivated by regulations and firms motivated by market demand. The analysis, based on the CIS data, finds support for the hypothesis that firms which focus on environmental goals face more and stricter barriers to innovation compared to firms that do not focus on such goals. Environmental firms and their innovation processes face limited access to financial and knowledge resources as well as an uncertain market demand to a

significantly higher extent compared to non-environmental firms. We also find support for our second hypothesis that the firms motivated by regulation face stricter barriers to innovations than the firms which are motivated by market demand.

Related to hypothesis 1, data on financial resources; "innovation costs too high", "lack of finance within the enterprise" and "lack of appropriate sources of finance from outside the enterprise" 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. Our analysis related to hypothesis 2 sheds more light upon the motivation behind the firms' focus on reducing its environmental impact and shows that market driven firms face less financial barriers than the regulatory driven firms. This might be because innovations motivated by market pull will have much more commercial potential than innovations motivated by regulations, however, market driven environmental innovations still face significantly more barriers than general innovations implying that the innovation process is more demanding for environmental firms than for non-environmental firms, regardless of their motivation. This result supports Frondel's (2007) finding that there are problems related to scaling up environmental products from niche markets to mass markets.

The limited markets for environmental innovations and the problems related to financing such innovations results in less focus on environmental innovations compared to non-environmental innovations which will lead to less environmental knowledge. Our results suggest that the lack of information on technology is one of the most important barriers to environmental innovations. This finding is supported by del Rio et al's. (2011) finding that non-environmental innovations will normally build on the existing knowledge of the firm,

whereas environmental innovations will often break with the normal production and will be incompatible with the firm's existing knowledge. To get access to the relevant environmental knowledge, firms might have to employ new people who possess this knowledge. There are, however, significant barriers associated with acquiring qualified personnel. Another solution to the lack of technological knowledge could be to cooperate with external partners like research organizations, customers or other firms. Cooperation is found to be more important in the development of environmental innovations than in the development of non-environmental innovations (De Marchi, 2012). Our finding supports this by showing that environmental firms experience stronger barriers related to cooperation compared to non-environmental firms.

Our analysis also shows that the level of R&D is significantly related to all the perceived barriers for innovation. An explanation to this is 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).

The overall conclusion from our study would be that environmental firms face stronger barriers to innovations than non-environmental firms. A more nuanced conclusion is that regulatory driven environmental firms face stricter barriers to innovation than market driven firms. This shows that market driven environmental firms are more similar to non-environmental firms than what the regulation driven firms are. This finding supports previous literature which assumes that regulation is the predominant difference between environmental and non-environmental firms and we conclude that policy and regulation induced environmental structural change are especially resisted and meet obstacles. Being hampered by a range of different barriers to innovation makes structural environmental changes harder. Our findings increase our knowledge on the inhibiting factors influencing the successful

development and commercialization of environmental innovations and add to the debate in the literature about the extent to which environmental innovation requires specific theorizing, by concluding that environmental innovations face stronger barriers than non-environmental innovations. We further make the crucial distinction between regulation driven and market driven green innovation processes that most prior research on green innovation has overlooked. Possibly, these two types of firms may differ in other respects apart from barriers to innovation. An obvious question for future research is to examine whether or not regulation or market driven green firms are more likely to develop and introduce new products in the market (a tech push side of the innovation process) and / or to have higher innovation sales (a demand pull side of the innovation process).

5. Implications

Firms need incentives to find solution to their pollution problems and to develop new environmental products and processes, and our findings have important implications for the development of policies to help firms engaged in the development of environmental innovations. Concluding that there are differences between regulatory driven and market driven environmental firms implies that there need to be policies directed towards both of these groups.

For market driven environmental firms policies should be developed to secure, and create new environmental markets. 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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