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Drivers for energy efficiency: an empirical analysis of Norwegian manufacturing firms

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Abstract

Manufacturing firms' ability to innovate and improve their energy efficiency (EE) is a key element in reducing emission of greenhouse gases (GHG) and attain international objectives of climate change mitigation. Despite an urgent need for more knowledge drivers for EE in manufacturing firms, there is still little research on the topic. Taking departure in the EE and environmental innovation literature we analyse the role of motivational factors and firm characteristics (education, R&D and cooperation strategies) as drivers for EE. Employing a logit model on a panel data from the Norwegian Community Innovation Survey (CIS) on manufacturing firms for the period 2010–2014, we examine how the drivers impact companies' investments in EE. Our empirical results show that the level of education and cooperation with competitors as well as universities and research institutions have a positive effect on investments on EE. The size of the company is also positively related to EE. We did however not find support for the hypothesis that R&D are positively related to EE investments.

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Keywords: Energy Efficiency; Drivers; Process Innovations; Manufacturing Sector; Norway

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1. Introduction

There is a global consensus of the correlation between energy consumption and greenhouse gas emissions (GHG). The industrial sector is one of the main consumer of energy (IEA, 2013), hence the sectors ability to innovate and improve their energy efficiency (EE) is an important mean to climate change mitigation.

Energy efficient technologies are both energy-efficient and cost-effective [1]. Increased energy prices, stricter environmental laws, and new supply and demand policies like the European Union Emissions Trading System (EU ETS) have generated increased call for EE and related reduction of energy costs in industrial companies.

However, research witness an unexploited potential for EE in manufacturing sector [2], and the existence of an EE gap [3]. The difference between the actual level of EE and what theoretically could be reached, given that all cost-effective technologies are implemented, is referred to as the EE gap [3]. Several policy initiatives, such as the EU 2030 energy and climate framework, are launched in order to close the gap. Although the industrial sector has continuously improved its EE over the last three decades [4], it still holds significant potential for further improvements [5]. In order to further stimulate EE in manufacturing firms, there is a need for a deeper understanding of the factors that drives the actual implementation of EE technologies.

An emerging literature indicate that there is a link between organizational innovativeness and EE in manufacturing firms [2, 6, 7]. However, this link is still not well understood. In this study we contribute to this literature by analyzing firm characteristics that drive EE innovations compared with other process innovative manufacturing firms. To do this we have developed a logit regression model on a panel data from the Norwegian CIS for the period 2010-2014.

2. Literature review and research hypothesis

Following the definitions in the Oslo Manual (OECD), the implementation of EE measures can be considered as process innovations. One could therefore assume that policies supporting general innovation would also lead to the implementation of EE measures. However, EE improvements has distinctive and additional features. Firstly, EE improvements are process-innovations. Research show that product and process innovations not necessarily have the same determinants [8, 9]. Secondly, EE measures can be considered as eco-innovations [10], which again are affected by the double externality problem [11]. Research on eco-innovations show that some drivers, such as public policies, cooperation and internal capabilities, play a more prominent role as specific determinants for such innovations [9].

To properly design policies to stimulate EE in manufacturing firms it is necessary to understand which drivers and firm characteristic that promote implementation of EE. A study on a multiple case study of the foundry sector in Italy found that internal R&D complemented with inbound open innovations practices have a positive effect on EE [6]. However, this study does not allow comparing characteristics of energy efficient firms with other innovative firms. Another study using data from the European Manufacturing Survey 2009 from five European countries, show that product and process innovations are positively related to adoption of EE technologies [2]. However, the study does not address the underlying factors causing this link. A third study, analyzed determinants of EE in Spanish innovative firms, using a logit model and data from the Technological Innovations Panel [7]. They found that company size, environmental motivation and organizational innovations are firm characteristics that have a positive effect on EE. However, their data sample includes both process and product innovations. A study from Germany used data from the German CIS and a probit model when studying determinants of eco-innovations [12]. The study, made a distinction of determinants by type of environmental impact, allowing identifying the determinants of eco-innovations within the firm (process innovations). The researchers found that cost savings are the main driver for energy saving innovations. In addition, they found that the reduction of environmental impact is a strong driver for air emission innovations. However, the study is based on an analysis of the specificities of eco-innovations compared with other innovations including both product and process innovations. Hence, it is impossible to determine to what extent the findings related to the differences in determinants of process vs product innovations. To gain some insights to this blind spot in the literature, we test some hypothesis based on previous research on EE and eco-innovations.

Research show that environmental innovations are more knowledge demanding than other innovations [13-16]. Advanced knowledge production require specialization of individuals. Higher education contribute to specialisation of individual, and increase the level of common knowledge in an organization [17]. The role of education has received little attention in the EE literature. Some of the few contributions argue that education and training stimulate a proper use of EE technologies, and increase EE awareness and culture [18]. Further it is found that industries with highly educated employees are more prone to EE investments [19]. These arguments leads us to our first hypothesis:

H_1: *The educational level of employees affect the company's propensity to invest in energy efficiency.*

Considering the role of internal R&D activities as drivers for EE the literature is ambiguous. The environmental innovation literature have found that R&D activities [15] and the existence of a specialized R&D department [20] are positively linked to environmental innovations. This relationship might be due to R&D activities role in developing organizational and technological capabilities [15], and the absorptive capacity of the firm [21]. Such capabilities increased the companies' ability to couple and integrate the specialized knowledge of individuals [17] and take advantage of external information [21]. However, studies on EE in manufacturing industries in Colombia [22] and Spain [7], found that investments in R&D are not statistically significant for investments in EE. Nevertheless, we consider the more extensive literature on environmental innovations as hypothesis that:

H_2*: Internal R&D activities are positively related to companies' propensity to invest in energy efficiency.*

Research on environmental innovations show that energy and resource efficiency innovations tend to be more complex innovation activities than innovation in general, that require knowledge inputs from a diverse set of sources [23]. External sources of knowledge are particularly important for environmental innovations compared with other innovations [16], suggesting that environmental innovative firms cooperate with external partners to a higher extent than other innovative firms [13]. The need for cooperation might be caused by a need for knowledge and competences not belonging to the core competences of firms [24]. Another argument relates to the need for reducing transactions costs and sharing risks [25]. Cooperation with external sources can also supplement internal R&D effort, allowing reducing internal R&D and related risks [13]. Hence we propose:

H_3*: R&D cooperation affects the companies' propensity to invest in energy efficiency.*

Organizational abilities and motivation affects the implementation success of EE projects [26]. The relevance of long term energy strategies and environmental awareness as drivers for EE is emphasised in a series of studies [1, 27]. In other words EE is strongly driven by environmental objectives and motivation. Further, even though the EE gap is observed [3], several empirical studies report that cost savings are an important motivating factor for EE [27]. This leads us to our forth hypothesis that:

H_4*: environmental objectives and energy savings motivates energy efficiency in manufacturing companies*

3. Research Methodology

To carry out the econometric analysis we use panel data from the Norwegian CIS for the period 2010-1014. The dataset consists of 19 198 observation, but our final sample is reduced based on the following criteria: (1) the sample covers firms that operates in manufacturing sectors, which is sector 10-32 determined by the Standard Industrial Classification defined by Statistics Norway, reducing the sample size to 6 021 observations; (2) the sample covers manufacturing firms that innovated in process innovations. Firms classified as process innovators had either introduced new or improved methods of production, introduced new or improved methods for storage, or introduced new or improved support functions such as systems for maintenance, purchase, accounting, and so on, leaving the sample size to 3 319 observations. Hence, 55,1 % of the observations in manufacturing sector reports process innovative activities in the period 2010-2014.

The dependent variable in our analysis is a dichotomous variable, a binary variable, as such a logit model is used and this equation is estimated:

$$p(IE_{it}) = \Lambda(\beta_1 + \beta_2 HDSHRE_{it} + \beta_3 DRSHRE_{it} + \beta_4 COOP1_{it} + \beta_5 COOP2_{it} + \beta_6 COOP3_{it} + \beta_7 ECOINN_{it} + \beta_8 MATINN_{it} + \beta_9 LSIZE_{it} + \beta_{10} RD_{it} + \beta_{11} SHRRD_{it} + \beta_{12} PUBLFUN_{it} + \alpha_i + \mu_{it})$$

IE_{it} is the dependent variable and has the value of 1 if the firm *i* report investments in research and development of energy efficiency at time *t*, and 0 if not. According to our hypothesis the independent variables can be divided into four different groups.

The first group of variables tells us something about the education level of the employees. The education level is measured as the level of formal education of the R&D staff (variables *HDSHRE* and *DRSHRE)*. More precise the variable *HDSHRE* is the share of the staff in the R&D department having a higher degree similar a Master's degree, and *DRSHRE* is the share of the staff in the R&D department that have a degree similar to a Ph.D.

The second group of variables related to the R&D activity of the company. The level of R&D is measured as sum of investments in R&D in general (RD), and the size of the R&D department (*SHRRD)*.

The third group of variables relates to the external cooperation (*COOP1 – COOP3*). *COOP1* has the value of 1 if the firm cooperate with suppliers, customers, and/or commercial laboratories and consultants. *COOP2* has the value of 1 if the firm cooperate with universities and/or public and private research institutions. *COOP3* has the value of 1 if the firm cooperate with competitors.

The forth group of variables (*ECOINN, MATINN and PUBLFUN)* is related to motivational factors related to the environment, economics and finance. The variable *ECOINN* has the value of 1 if the process innovation is motivated by reduction of environmental impact (with a high or medium importance). The variable *MATINN* has the value of 1 if the purpose of the process innovation was motivated by reduction in material and energy costs (with a high or medium importance). The variable *PUBLFUN* has the value of 1 if public institutions fund innovation projects within the firm. At last we also control for the size of the firm, where the variable *LSIZE* is the log of number of employees in the firm.

$\beta_1 - \beta_{12}$ are parameters to be estimated, α_i is an unobserved time invariant individual effect, and μ_{it} is a zero-mean residual. The model is estimated as a panel model using random effects, since we are observing the firms over several years and the firm has the opportunity to either do R&D in other environmental related energy or not at each time *t.* Not all firms occur at all *t's* meaning we are operating with an unbalanced panel.

4. Results and conclusions

Our interest lies in determinants affecting process innovative manufacturing companies' ability and willingness to engage in EE. The estimation results of the logit model are given in Table 1.

Table 1: Estimated parameters

Variables	Variable description	Estimated coefficients	Odds Ratios	t-statistics (p-value)
HDSHRE	Educational level of individuals in R&D department	2.12	8.33	3.86 (0.000)***
DRSHRE	Research competence of individuals in R&D department	1.64	5.15	2.93 (0.003)**
RD	R&D intensity in sum R&D investment	-0.01	0.99	-0.28 (0.782)
SHRRD	R&D capacity in number of employees	1.54	4.65	1.39 (0.164)
COOP1	Cooperation along the value stream	-0.10	0.37	-0.25 (0.806)
COOP2	Cooperation with knowledge institutions	1.23	3.41	2.91 (0.004)**
COOP3	Cooperation with competitors	0.59	1.86	1.64 (0.102)*
ECOINN	Environmental motivation	0.99	2.68	2.93 (0.003)**
MATINN	Economic motivation	0.21	1.24	0.67 (0.503)
PUBLFUN	Financial motivation through public investment incentives	0.34	1.41	1.01 (0.314)
LSIZE	Company size in number of employees (log)	0.73	2.07	3.72 (0.000)***
Constant		-10.85	0.01	-8.32 (0.000)

*, **, *** - significant at 10 %, 5% and 1 % respectively

The results of the logit model, presented in Table 1, show that the variables related du educational level of employees in R&D department (HDSHRE and DRSHRE*)* are significantly related to the EE of the firm. Hence, the model strongly support our first hypothesis (H_1) that higher education serve as a driver for EE. Our findings coincides, with the results obtained in previous studies addressing the relevance of education and staff training as drivers for EE [19].

Our second hypothesis (H_2) assuming that internal R&D drives EE is not supported by our logit model (RD and SHRRD). Hence, EE process innovation does not seem to need significantly more R&D efforts, compared with other process innovations. The results coincides with previous studies on EE innovations [7, 22], but contradict with research on environmental innovation in general [13, 15]. Previous research show that a flexible and effective internal organization [25], and that collaborative attitude among different teams and departments [28] have a positive effect on EE. Hence, our findings might indicate that the EE innovative activities occur by the help of the well-educated R&D staff, but takes place outside the frames of the R&D department.

The third hypothesis (H_3) analyze the importance of cooperation with external partners. It is partly supported by the model. Cooperation with the research sector (COOP2) has a significantly positive effect on EE. This findings coincide with previous research arguing that environmental innovations are knowledge demanding [14, 16] and that interaction and knowledge exchanges with academia and scientific agents have a positive effect on eco-innovations [13], and EE [29]. Our model also show that cooperation with competitors (COOP3) has a positive effect on EE in manufacturing firms. This result can be seen as a supplement previous research fining a positive correlation between a competitive environment and EE [1, 30]. However, in the case of EE it seems that it is not only the mere competition that leads to EE, but also the potential for knowledge exchange and reduction of risk. Considering cooperation with actors along the value stream (COOP1), we find that cooperation with customers, suppliers, and consultants do not have any significant effect on EE compared with other process innovative companies. The limited relevance of customers are in accordance with previous studies on cooperation strategies of eco-innovative firms [13], and studies on customers influence on the EE in manufacturing industries [31]. Our result somehow contradict with previous research arguing the existence of technological interdependencies between eco-innovators and their vendors [13], and the positive effect of technology suppliers, installer and other experts on EE in SME [32].

The fourth hypothesis (H_4) analyses the impact of motivational factors. Our model shows that environmental intentions (*ECOINN)* are a significant and positive driver for EE. This finding coincide with previous studies pointing to the importance of environmental strategies, corporate social responsibility and awareness as drivers for EE [7]. The model also tests for economic objectives (*MATINN)* as a driver for EE. We do not find that the objectives of reducing material and energy cost have any significant effect on EE. This finding might be surprising considering previous research results. When managers are asked about drivers affecting the decision to invest in or implement EE technologies they often refer to cost reduction from lower energy use as one of the most prominent drivers [27]. Even though our result contradicts with previous research, this does not necessarily mean that the results are conflicting. Our model analyze if there are any significant differences between manufacturing companies engaged in EE compared with other process innovative companies. Process innovations are in general are motivated by efficiency and cost reduction [12]. Hence, our results does not reject that EE investment can be motivated by economic driver, it only states that there are no significant difference in the economic motivation when comparing investments in EE and other process innovations. Nevertheless, it is worth mentioning that even though cost reduction is reported as a strong driver, studies assessing actual investments in EE find that investment cost and payback to be determining factors [33]. This implies that companies in general are more sensitive to initial cost than annual saving. Further, our model did not find any significant relation between public funding (*PUBLFUN)* and EE. Previous research confirms this result. In studies of both eco-innovation and eco-efficiency models the public funding is only significant in the case of eco-innovations, whereas if the analysis is limited to EE innovation no positive effect is found [7, 12, 13]. However, when asking managers about motivating drivers for EE investment, they consider public investment subsidies as a prominent driver [34]. This is a paradox that needs to be investigated further.

Finally, we have controlled for firms size (*LSIZE)*. We find that firm size is a firm characteristic positively related to EE. This is a result that coincided with the results obtained in other studies [7, 13]. The significance of size can be caused by larger firms' exposure to stronger competition in an international environment [30]. One might assume that larger companies have higher energy consumption and thereby energy cost and have therefore stronger incentives to become more EE. Larger companies might also benefit from relevant resources such as; competences, organizational slack, network and capital needed to engage in EE projects [30].

Our results give us some interesting findings about firm characteristics and motivational factors that can be considered significant EE in manufacturing firms. We also find that the eco-innovation literature in general to a large extent contradict with our model and other research results obtained on studies focusing on EE in particular. These findings imply that EE innovations differ in certain aspects from other eco-innovation activities, and one should therefore be careful adopting theory from the eco-innovations literature directly on EE. This also precaution also applies in the design of policies for EE.

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