MASTER'S THESIS

What Determines Firms' Investments in Pollution Abatement and Energy Efficiency Technology?

An Econometric Analysis of Swedish Industry

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An econometric analysis of Swedish industry*

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ABSTRACT

The main purpose of this study is to examine what determines firms' investments in abatement and energy efficiency technologies, and a secondary purpose is to test the presence of a crowding-out effect between energy conservation investments and abatement technology investments. The data set consisted of 78 energy intense Swedish firms over the time period 2004-2010. The dependent variables in the econometric analysis were drawn from a data set from Statistics Sweden on environmental protection expenditures. Six independent variables were implemented in the econometric models. The results from the models show that different firm characteristics are of importance for the investment decisions, in particular firm size and energy intensity. Some of the results indicated that there could exist a crowding-out effect, e.g., since energy prices had a negative impact on pollution abatement investments.

SAMMANFATTNING

Det huvudsakliga syftet med denna studie är att undersöka vad som kännetecknar företag som investerar i miljöskyddskostnader och energieffektivisering. Ett sekundärt syfte är att testa om det finns någon typ av undanträngningseffekt mellan energibesparande investeringar och miljöskyddsinvesteringar. Det datamaterial som användes bestod av 78 energiintensiva svenska företag över tidsperioden 2004-2010. Företagens utgifter rörande investeringar i miljöskydd respektive energieffektivisering har använts som beroende variabler medan sex stycken förklarande variabler inkluderats i de ekonometriska modellerna. Resultaten från modellerna visade att företagsspecifika faktorer påverkar benägenheten att göra dessa investeringar, inte minst storleken på företaget samt dess energiintensitet. Några av resultaten indikerade också att det kan finnas en undanträngningseffekt, till exempel i form av att ökade energipriser tenderar att ha en negativ påverkan på nivån på investeringar i miljöskydd.

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INTRODUCTION

1.1 Background

Global warming and climate change have lately got higher priorities, policy makers deal with a problem that is affecting the living quality for humans. Greenhouse gases such as carbon dioxide (CO_2) and nitrogen oxides (NO_X) are heavily related to global warming and are therefore often discussed in media and science. These greenhouse gases mainly stem from manufacturing industries, and where the energy and industrial sectors stand for the largest share of total emissions (EPA, 2013). With economic growth follows increasing pollution so it is important for policy makers to find ways to keep economic growth sustainable. Since the largest part of emissions comes from the energy sector, policy makers often try to regulate this market in order to reduce the total energy use. To create a sustainable growth firms can invest in energy efficiency technologies, or they could invest in types of abatement technologies (IEA, 2011).

Global warming is an international problem and it requires cooperation between countries. In 1997 the Kyoto Protocol was signed where the participating countries were legally bounded to work for reducing their emissions, a target level was stated and it was supposed to be reached within the time period 2008-2012. This protocol is one of the steps closer to an international cooperation towards an effective global emission reduction (Böhringer, 2003). Environmental policy is an important factor for reducing greenhouse emissions, if rightly constructed it creates a more efficient market. The aim of a low-carbon economy is promoted in European countries and in order to reach this certain efforts are required. Therefore it is important to develop new technology, invest in abatement systems and to become more efficient in the production process (EC, 2013). In order to facilitate green policy decisions the European Commission have adopted a regulation requiring that its member countries report statistics on environmental protection investments on an annual basis. Furthermore, in Sweden a law was implemented in 2001 to secure that a good quality and high response rate of statistics on environmental protection is achieved (SCB, 2012a). Between the years 2010 and 2011 an increase of investments overall occurred with nearly 1.1 billion SEK, while total expenditures for environmental protection ended up to 12 billion SEK at year 2011. Most of the expenditures paid for protection of the environment concerned air pollutions and water waste (SCB, 2012b).

It is desirable for policy makers to create incitements for firms to switch to a cleaner production process, and to reduce their pollutions, therefore many studies have tried to examine what factors trigger firms to do so (see, for instance, Hammar and Löfgren, 2010; Frondel et al., 2007a; Frondel et al., 2007b; Río et al., 2011). However, since there are very few studies so far that have analyzed if the influential factors differ between clean abatement investments (investments that prevent pollutions in the process) on the one hand and end-of-pipe solutions (reduces emissions in the end of the production) on the other, further research on this area is still necessary. If there is a difference between the different types of abatement investments one could assume that the drivers for investments differ between them as well and thus, this calls for more research. Policy makers should ask themselves what triggers investments and how they can make sure that they create the right incitements for each type of abatement technology. In some cases it is more preferable to use clean abatement technologies in order to create a cleaner production process (e.g. when dealing with very dangerous pollutants etc.), therefore we also need to know what triggers firms to choose one investment type over another.

This study will add to the existing literature by using three dependent variables in different models, where the two first intend to see if the determinants of clean abatement technologies and end-of-pipe solutions, respectively, differ. The third dependent variable will be used to see if there exist any crowding out effect between energy efficiency investments and abatement technology investments. A crowding-out effect in this case would indicate that firms instead of investing in abatement technologies choose to invest in energy conservation technologies instead. The crowding-out effect however, is not fully something negative, since a reduction of energy use itself is a good thing for the environment. Nevertheless, it is still important to understand the difference between different types of investment alternatives because sometimes one type of abatement investment is preferred over another, depending on the impact the pollution has on the environment.

1.2 Purpose

Today many countries aim to reduce the level of pollution due to the dangers it causes to society and the associated costs. Most policy makers have high priorities on environmental damage issues and seek to find effective ways to generate a better environment. This study intends to add to the literature an understanding of why firms choose to invest (or not to invest) in abatement technologies.

The purpose of this study is to find out what determines firms' investments in pollution abatement technologies.

1.3 Methodology

In order to find out what determines firms who choose to invest in abatement technologies an econometric approach have been used. The econometric approach has been the most suitable for the purpose of this study since a wide range of available data can be found for firms that invest in abatement technologies. A data set that consisted of 78 Swedish firms was used, which included variables that previous studies have found important for abatement investments (see section 2.1). All data that are included in this study comes from two different sources and constitute secondary data. Detailed information about firms' have been collected through phone interviews, which then was complemented with secondary data collected from SCB. Originally the data set in this study were supposed to be used to see "what determines firms who are energy intense", and thus, some missing cases followed together with several zero values. To evade the problems that can occur when using a data set with many zeros a censuring regression model have been used, typically known as the Tobit model.

Three dependent variables were chosen for this study, where the two first variables intend to see if it differs between investments in clean abatement technologies and end-of-pipe solutions. Since this study has a sub-purpose (to see if there exists any crowding out effect between energy conservation investments and abatement technology investments), a third dependent variable have been used. This is information on investments in energy conservation and/or heat cost savings. All the data for the dependent variables measure total expenditures, and have been collected from Statistics Sweden (SCB).

1.4 Scope

This study aims to investigate what determines firms who invest in abatement technologies, and it includes 78 Swedish firms. The chosen time period includes the years 2004-2010. The firms included in the data sample have been drawn from the following sectors; mining, food, steel, foundries and firms producing non-ferrous metals. This means that the study is limited to firms with an energy-intensive character. Also, none of the firms included in the sample had less than 200 employees. Furthermore, no distinction between small and large investments has been made in this study. Thus, the purpose is mainly to see which variables can explain firms' investments in abatement technologies and energy conservation technologies.

1.5 Outline

In chapter 2 an overview is provided of previous studies that have been made in the area relevant to the purpose of this study. Chapter 3 discusses theoretical perspectives that can explain why firms choose to invest in abatement technologies, and it mainly focuses on the relationship between industrial competitiveness and environmental performance. The econometric model and data sources and definitions are described and discussed in chapter 4. Chapter 5 presents the results, which are analyzed and discussed. Finally, chapter 6 contains some concluding remarks.

CHAPTER 2

AN OVERVIEW OF PREVIOUS STUDIES ON ABATEMENT TECHNOLOGY INVESTMENTS

In this chapter an overview of previous studies that are relevant for the present study will be given. The focus has mainly been on studies that have tried to examine why firms invest in abatement technologies and investigate the factors that are important for these types of decisions.

2.1 Summary of previous studies

In order to find relevant literature mainly two databases have been used: Google Scholar and Scopus. Examples of keywords that have been used in the search are: Economics, Environmental policies, environmental protection, abatement investments. Also the use of reference lists has been important in order to find relevant articles.

Since this study builds on a study made by Hammar and Löfgren (2011), this article is also one of the most relevant. The study by Hammar and Löfgren aims to examine what factors motivate firms to invest in abatement technologies and to see if the factors differ between clean abatements and end-of-pipe solutions. Below follows a table which displays the articles that has been summarized.

Table 1: Overview of relevant literature

Author	Publishing Year	Purpose	Method	Results
Hammar and Löfgren	2010	Explaining adoption of end of pipe solutions and clean technologies	Econometric analyses	There are different drivers between the two abatement technologies
Löfgren et al.	2013	Examines what effect the European Union's Emissions Trading Scheme has on Swedish firms	Econometric analyses	Firm characteristics have a significant effect on the probability of investing in carbon mitigating technologies.
Frondel et al.	2007a	Analysing the factors that drive firms to invest in end of pipe and cleaner production technologies	Econometric analyses	Incentives to invest in these two types of technologies are different
Rio et al.	2011	Finding the determinants for investing in environmental technologies in Spain	Econometric analyses	Determinants for investments are likely to differ between environmental technology types
Löfgren et al.	2008	The effect of uncertainty on pollution abetment investments	Econometric analyses	Uncertainty has an impact on investments
Leiter et al.	2011	The impact of environmental regulations on investments	Econometric analyses	The environmental regulations have a positive but diminishing impact on investments
Anton et al.	2004	Incentives for adopting environmental managing system (EMS)	Econometric analyses	Market-based pressures are significant motivators for adopting EMS
Frondel et al.	2007b	Triggers for environmental management and innovation	Econometric analyses	innovation behavior is mainly correlated with the stringency of environmental policy

Hammar and Löfgren (2010) try to explain why firms decide to adopt for abatement technologies. In order to measure technology adoption they have used data on environmental protection investments (EPI), which are provided by Statistics Sweden. The data are collected with a yearly survey. In the study they are examining four different industries in Sweden, the pulp and papers industry, the chemical industry, the manufacture of basic metals industry and the energy and heating sector. In the data used it can be seen that it is as common to make an investment in clean technology as it is to make an investment in an end-of-pipe solution. In their model they have chosen to test for five explanatory variables. The first is "learning by doing and knowledge", which they motivate by noting that with a better knowledge of available technologies and how to use it, a firm is more likely to adopt new technology. The second one is "complementarity between clean technology and end-of-pipe solutions". The authors want to investigate if the two abatement technologies are complements, because in case of being substitutes they will tend to crowd each other out. The third variable used is input prices, which include wage and energy prices. The fourth one is "earlier investment", which they argue could be seen as a complement to learning by doing. The last one is "other firm characters" where they choose to use a size variable measured in revenues.

The results show that the two investments are complements weaken. They find that investments in clean technology are important for investments in end-of-pipe solutions, while the opposite does not necessarily hold true. Also learning by doing seemed to be significant for clean technologies but not for end-of-pipe solutions. Energy prices on the other hand were shown to be significant for end-of-pipe solutions but not for clean technologies. Further findings were that firms with higher paid workers tend to more often make environmental protection investments. And finally, the larger the firm, in terms of revenues, the more likely it is to invest in end-of-pipe solutions. Conclusions made is that the probability of clean technology investments is larger if the firm has R&D expenditures related to environmental protection, while that factor seems to be less important for end-of-pipe solutions. Finally, when firms decide to invest, they are likely to invest in both types of technologies.

Löfgren et al. (2013) examine what effect the European Union's Emissions Trading Scheme (ETS) had on Swedish firms' investments in technologies that reduce carbon emissions. The authors have used a data sample that covers all sectors in Sweden that are included in the trading system. The time period used was from the year 2002 to 2008. All investments that have been made to reduce carbon dioxide emissions during this time period have been collected from Statistics Sweden, and were used as a dependent variable for this study. The explanatory variables included were carbon dioxide prices (taxes included), over-allocation, green R&D, earlier investments, fuel use, fuel price, wages and revenues from sales. In order to test the effect of the European Union's Emissions Trading Scheme on Swedish firms the authors have used a two-step analysis, where the first step covers the whole time period and the second step with the time period of year 2005-2008. Since the trading system was implemented first in year 2005 this two-step analysis is supposed to better capture the effect of the implementation. Furthermore, the authors have divided the investments into small investments (investments below € 1 million) and large investments (investments equal to or above € 1 million).

The results found for small investments were that the implementation of the ETS program had no statistically significant effect on firms' investments in carbon mitigating technologies. No significant effect could be found for either the carbon dioxide price, over allocation or green R&D. However, earlier investments had a positive effect on small investments in carbon mitigating technologies. Here the authors argued this as learning by doing seem to have a complementary effect on small investments. The results for large investments were not significant for the carbon dioxide price or an over allocation, neither seemed the implementation of the ETS program to have an effect. R&D was significant for the model using the time range 2002-2008, also earlier investments was significant for large investments. The authors' point out that the results for large investments should be considered carefully since the data that were used is not suitable for explaining why firms makes investments larger than 1 million SEK.

The conclusions drawn were that for both large and small investments firm characteristics seemed to be important (e.g. earlier investments and energy intensity etc.). Since they could not find any significant effect for the implementation of the ETS program for large investments, they assume it is because the time period was too short. The conclusions drawn were that the implementation of the ETS program did not seem to have a significant effect of firms' investments in carbon mitigation technologies, and secondly, firm characteristics seemed to be of great importance. The authors argue that the reason for the insignificant effect is that the ETS program has been too generous, leading to a lower price than what would be preferable. Another conclusion is that the time period is far too short to give any good explanation to why firms choose to invest in large investments (amounts equal to or above 1 million SEK).

Frondel et al. (2007a) analyse firms' choice between different environmental technologies. They aim to see if internal and external factors support the environmental innovation decision for cleaner production. A comparison has been made between end-of-pipe technologies and clean technologies. Data were collected from an OECD survey made in 2003 including seven OECD countries. The data were divided into three different categories; end-of-pipe technologies, cleaner production technologies and no-abatement option (the last one representing the situation where no new environmental production technologies are implemented). Furthermore, they assumed that abatement technology investments are affected by five different factors, including:

1) Motivations (such as corporate image improvements).
2) Environmental policy instruments (e.g. taxes, regulations etc.).
3) Management tools, different management practises (e.g. health and safety).
4) Pressure groups (labour unions and environmental organisations).
5) Facility characteristics (e.g. size and turnover etc.).

The results found were that policy stringency and regulatory measures were positively correlated with end-of-pipe technology investments but not with clean abatement technologies. Clean abatement technologies on the other hand seemed to be market-driven. Internal forces (e.g., corporate headquarters and management) had an impact on both end-of-pipe technologies and clean abatement technologies while environmental management tools appeared to be important only to clean technology investments. Conclusions drawn were that clean abatement technologies were more frequently used for both environmental and economic reasons, while end-of-pipe technologies depended more on environmental policies. One final conclusion made by the authors were that by widening the cost gap between the two abatement technologies it could stimulate investments in clean abatement technologies.

Río et al. (2011) aim to analyse which factors affect environmental technology investments. This study analyses the Spanish industrial sector and compares end-of-pipe technologies and cleaner technologies. Data on firms' expenditures in environmental protection were collected from the Spanish National Statistics Institute. The rest of the data were collected from the following sources; Industrial Survey of Firms, DIRCE and R&D statistics. The time period used was from the year 2000 to 2006. The results show that environmental technology investments are strongly correlated with the stringency of environmental regulation. Four other variables were also found to have a significant relationship with investments in environmental technologies, including: intensity of human and physical capital, intensity of R&D and firm age. The positive relationship between environmental technology investments and physical capital investments suggests that recent capital investments are not a barrier to environmental investments. The results also showed that modern firms are more likely to invest in environmental protection technologies. One negative relationship found was that firms facing strong international competition were less likely to invest in environmental protection technologies. Conclusions drawn were also that R&D investments should be encouraged because this will improve the technology capability of firms and their human capital.

Löfgren et al. (2008) are attempting to measure the impact of uncertainty concerning future prices of polluting fuel on a firm's decision to invest in abatement technologies. Here they chose to derive the threshold condition on the price of the polluting fuel for which a firm facing uncertainty will decide to invest in a new abatement technology. Essentially they are trying to estimate the hurdle rates for abatement investments. The study is limited to the pulp and paper industry and the energy and heating sector. Data used were an unbalanced panel data set for the years 2000-2003, which was collected by Statistics Sweden. The data included information about firms' investments in air pollution abatement technologies and the price of fuel included all relevant taxes. The fuel price was measured as the average price derived from 12 different types of fuels. The data were also divided into two samples; investments in end-of-pipe solution investments and clean abatement technologies.

The results indicated that firms in the pulp and paper industry and energy and heating sector had delayed their abatement investment decisions for the chosen time period (2000-2003), because of the uncertainty on future prices for polluting fuel. Their findings about hurdle rates were that with a lower capital cost the estimated hurdle rates would increase. Conclusions drawn were that firms in these two sectors may delay the adoption of abatement technologies because of uncertainty about future fuel prices. Also, they concluded that hurdle rate values in the energy and heating sector were significantly higher than the values for the pulp and paper sector. This, they argue, could be a reflection of higher energy costs for that industry.

Leiter et al. (2011) analyse the importance of environmental regulation in European countries. Here the authors try to see if tighter environmental standards are connected with a higher or lower investment at a given location. There are four types of investments the authors are interested in, including: gross investment in tangible goods, gross investment in construction and alteration of buildings, gross investment in machinery and productive investments. The data used in this study were taken from the Eurostat databases. The total expenditures on environmental protection and revenues from environmental taxation were taken from the Environmental Accounts Database. Information on country-industry-specific variables were found from the Annual Enterprise Statistics. The dataset included 21 countries for the time period 1998-2007. In the results they found that all types of investments were positively correlated with environmental regulations, except for very high regulations. Their conclusions were that environmental regulations have a positive impact on investments and they also conclude that the positive effect is diminishing with tighter regulations. Moreover, tighter regulations make firms more effective, with less use of resources in the production process. If the environmental regulations are too high though, the benefits seem to be lower than its costs.

Anton et al. (2004) aim to examine which factors influence the adoption of environmental management systems (EMS) among firms, and also to establish the extent to which the comprehensiveness of the EMS has an impact on toxic release intensity. The data used were primary data on EMSs for S&P 500 firms that are included in the Corporate Responsibility Center for the years 1994-1995. The results found were that environmental regulations push firms to be more proactive in managing their environmental performance. It also showed that larger polluters are more likely to adopt a more comprehensive EMS. The results also showed that consumer pressure has a direct impact on a firm’s management strategy; firms with a closer contact to the consumers are likely to be more environmental proactive. The authors’ conclusions were that the threat of liabilities and market-based pressures from consumers, investors and other firms are significant motivators for the adoption of a more comprehensive EMS. Moreover, the adoption of EMS has a significant negative impact on the intensity of toxic releases. Finally, the authors suggest that promoting the adoption of EMSs (mostly by firms with a large toxic release intensity) can be considered an effective policy tool.

Frondel et al. (2007b) investigate two things, the first one is finding incentives for a firm’s voluntary adoption of EMSs, and the second one is to see what triggers environmental innovation behaviour. EMSs are expected to improve the environmental performance because it should enhance environmental innovation activities in companies’. However, according to the authors this has not yet been proven. In order to investigate the two questions on hand, the authors used a plant- and firm-level data set for German manufacturing. The data were collected from an OECD survey which was done in 2003 and consisted of 7 OECD countries. One of the tasks of the survey was to analyse the EMS adoption decision of facilities. The variables used were: pressure groups, motivations, environmental policy tools and facility characteristics. Pressure groups included public authorities, interest groups, internal forces and environmental organisations. Motivations included improvements of the corporate image and cost savings. Internal forces were such as taxes, technology standards and input bans. And finally, facility characteristics included the facility size and the relevance of environmental impacts of pollutions.

The results showed that the adoption of EMS was strongly correlated with an expectation of a better corporate image. In contrast, the result also showed that cost savings was negatively associated with EMS adoption. Here the authors argue that it is probably because the respondents' of the survey expected that EMS adoption would be costly. Finally it seemed that policy stringency had no impact on EMS adoption. Further findings from the results were that the adoption of EMS does not necessarily trigger environmental innovation. Moreover, firms who are adopting EMS also seem to invest in clean technology, while firms that do not adopt EMS tend to invest in end-of-pipe solutions. Conclusions drawn were that firms' decision for the voluntary adoption of an EMS could be explained by rational self-interest and corporate image improvement. However, pressure groups and policy instruments did not seem to push for EMS adoption.

2.2 Conclusions

It can be concluded that this area has been widely researched in the past, and that the results tend to differ across studies. One obvious explanation for the difference in results is that the previous studies differ in both the models specified and the choice of data, e.g. different countries, industries etc. The most common method used in the previous studies has been the use of econometric techniques. It can also be concluded that the choice of data is of importance when examining what factors drives firms to invest in abatement technologies. Even if this area has been studied widely before, it still needs further research because it is important to find ways that generate a sustainable economic growth.

This study intends to add to the existing literature in two ways. First, it adds to the understanding of why firms choose to invest in clean abatement technologies and/or end-of-pipe solutions. Second, it develops existing work by examining if there exists any crowding out effect between abatement technology investments and energy conservation investments. This area is still an important issue to research because of the problems the world is facing with the environment caused by pollutions.

CHAPTER 3
THEORETICAL PERSPECTIVES ON FIRMS' CHOICE TO INVEST IN ABATEMENT TECHNOLOGIES

This chapter discusses theories that could help explain why firms choose to invest in abatement and energy conservation technologies, and adopts the approach of neoclassical production theory.

Often in economic theory it is assumed that markets operate on an efficient level, however this is often not the case due to the existence of market failures. Since we are dealing with resources that are scarce and human needs that are infinitive, the creation of a sustainable economic growth is crucial. For this, it is important to continually work on technical development and innovations (Field, 2008). Many studies have tried to analyze what factors affect firms' choice to invest in abatement technologies, some of the finding have been summarized by Kemp and Pontoglio (2011) and Carlos Montalvo, (2008). These authors concluded that policies are important but also the capacity of a firm. The following sections discuss theoretical perspectives on a firm's choice to invest in new technologies (abatement and energy conservation technologies in particular for this study). The first section highlights the types of costs and benefits that are associated with environmental protection investments, and this is followed by a second section which takes the approach of the neoclassical production theory in terms of environmental performance. The last section describes an alternative perspective, and here the relationship between industrial competitiveness and environmental performance is discussed.

3.1 Costs and benefits of environmental protection investments

Since firms are assumed to act under profit-maximizing behavior they would not undertake an investment if its benefits did not exceed its costs. To measure the value of an investment a cost-benefit analysis is often made, and this analyzes the costs and benefits that can be expected from the investment. Possible benefits from investments in cleaner technologies on a firm level are: efficiency gains, cheaper to meet environmental requirements and also for some producers it could mean an access to new markets where consumers are willing to pay a higher price for greener products. On a society level the investment could lead to increased environment quality. The costs on the other hand are linked to uncertainty, where the benefits from an investment cannot be sure to exceed the total costs (Montalvo, 2008). Total costs for an investment on firm level can be divided into direct costs and indirect costs, where direct costs includes costs such as new equipment, administration, production disturbance and a switch to more expensive input-goods. Indirect costs include costs as alternative costs and production losses (Söderholm, 2012). A simple illustration of the costs and benefits for an investment in cleaner technologies can be seen in figure 1.

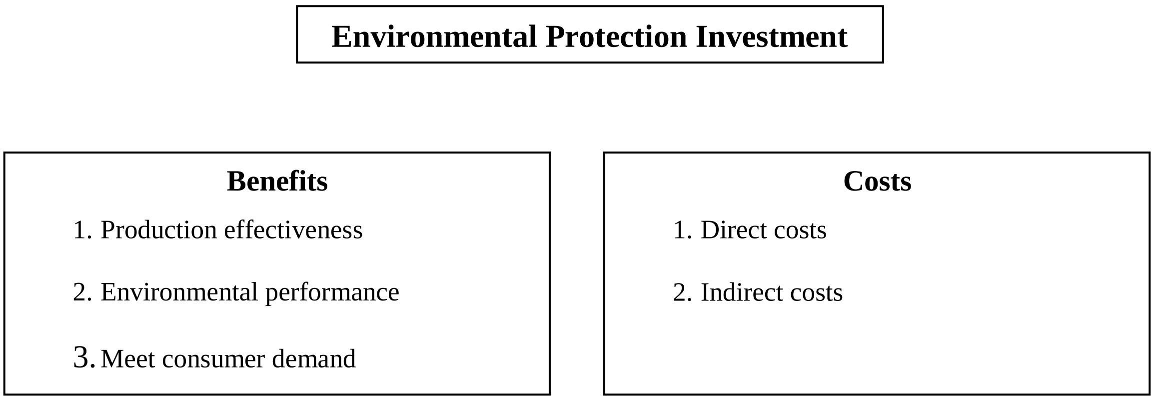

Figure 1: Costs and benefits for environmental protection investments

In Figure 1 the benefits of environmental protection investments have been divided into three groups, where the first one is categorized as “production effectiveness”, the second one as “environmental performance” and the third one as “meet consumer demand”. Costs have been divided into two groups, where one is direct costs and the other one is indirect costs. A further discussion about these different types of benefits will be made in the following two sections.

3.2 Three drives for environmental protection investments

As mentioned before investments in environmental protection technologies can give rise to production effectiveness. This can be explained with the approach of the neoclassical production theory. In this theory we assume that every firm rules under a production possibility frontier (PPF) where efficiency in production is reached where the indifference curve tangent to the frontier. To simplify, we can assume a firm which produces two goods, A and B, with a fixed amount of inputs (e.g. capital, labor, material). The production frontier then shows the maximum amount of outputs a firm can produce given the amount of inputs used. The production possibility frontier is also limited to the best available technology on the market, and thus, it is impossible to produce at a level that lies outside the frontier. Where on the frontier a firm choses to lie depends on which mix of goods that gives the highest utility, that is, where the indifference curve, representing consumers' preferences, is tangent to the frontier (Perloff, 2009).

In figure 2 we can see a production possibility frontier, which shows two outputs, where one is environmental goods and the other is ordinary goods and services.

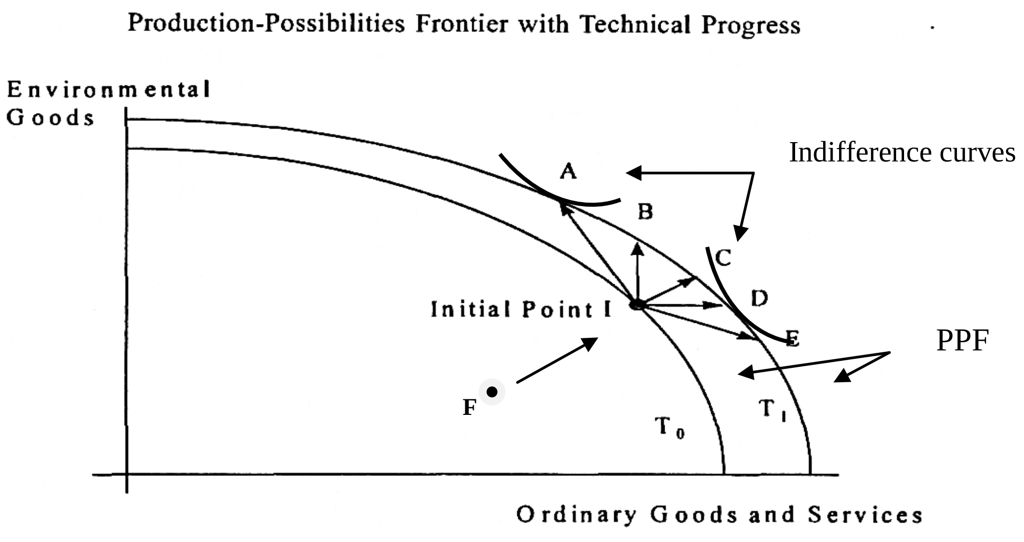

Figure 2: Production-Possibility Frontier

Sources: Based on DeCanio (1997)

In an article by Färe et al. (2006) an environmental performance index was constructed by the creation of a joint production efficiency, which uses a ratio between bad outputs (pollutions etc.) and good outputs (ordinary goods and services). Furthermore, the authors state that one cannot produce good outputs without producing any kind of bad outputs. To increase environmental performance it is desirable to reduce bad outputs without giving up the level of good outputs. In Figure 2 above a decrease in bad outputs would mean an increase in output of environmental goods. If we assume that a firm is currently operating on its production-possibility frontier in the initial point I in time period T_0, an investment in environmental protection technology would increase the firm's production possibility leading to the new production possibility frontier equal to T_1. Here the investment could give an increase in effectiveness in two ways, either by producing more of the environmental goods (reducing bad outputs) or increasing the output of ordinary goods and services. It could also result in an increase of both environmental goods and ordinary goods, as the case is at point C in the figure.

Where on the frontier a firm chooses to produce on is decided by relative prices between the two goods, where consumers' preferences can have a positive effect on increased environmental goods as well as environmental requirements, for example point A or B in the figure. The new technology creates a movement along the frontier to the left, where more of the environmental goods and less of ordinary goods now are produced. On the other hand, if it is more profitable to increase the output of ordinary goods a firm would lie more to the right side of the frontier, example point D or E. There is also the possibility that a firm is operating on an ineffective production level, equal point F in the figure, which lies inside the possibility production frontier. By investing in new technology a firm can become more aware about its production process so that inefficiency can be observed and dealt with. This would create a switch from point F to a point that tangent to the frontier (DeCanio, 1997).

A second case could be that when firms are producing at a point on their production possibility frontier, consumers changes their preferences to a level that makes it necessary for firms to invest in new technology. In Figure 3 below we can see this movement along a firm's production possibility frontier due to a change in consumers' preferences.

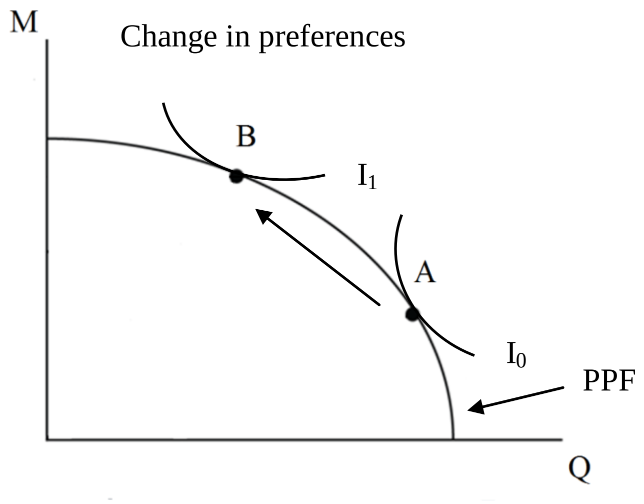

Figure 3: Changes in consumer preferences

If we assume that a firm is currently operating at point A on its production possibility frontier but a change in consumer preferences occurs (a switch from I_0 to I_1), and consumers now demand more of environmental goods (M). Then a switch from A to B would take place. Firms would need to invest in new technology which produces more of environmental goods, leading to a movement along the frontier to the new point B where the new indifference curve (I_1) tangent to the production possibility frontier. By investing in new technology firms can meet its consumers' new demand.

A third case that could occur is that the government regulates the market which forces a firm to produce a given amount of environmental goods. In Figure 4 below we can see the effect of an implementation of an environmental requirement.

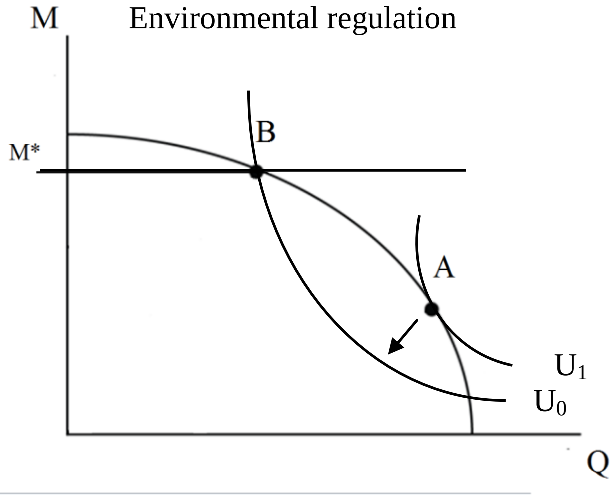

Figure 4: Environmental regulation implementation

If we assume that a firm is currently producing on its production-possibility frontier at point A in the figure above and an environmental regulation is implemented which requires that firms produce a given level of environmental goods (M) equal to point B, it then forces firms to invest in new technology which changes the production output. Whether or not a firm wishes to produce the level which is required, it is now forced to fulfill the requirement and thus, a movement from point A to B would occur. We can see in the figure that by forcing firms to produce a given level of environmental goods, it lowers the utility for a firm. We see a switch from U_1 to U_0 where a firm is now not operating on a utility maximizing production level. Not only is the consequences by this that firms' lose utility; if the regulations is not correctly made it could also lead to welfare losses for the society. Prices of goods would rise due to increased cost for firms leading to a decrease in demand and supply.

3.3 Industrial competitiveness and environmental performance

Michael Porter developed in 1995 a relationship between industrial competitiveness and environmental performance which in another way describes why firms invest in abatement technologies. Porter discusses firms' competitiveness on an industry level in terms of productivity, and according to his theory environmental regulations can give rise to innovations in two ways. First, firms get better in dealing with pollutions where it occurs (end-of-pipe solutions) and secondly, regulations can improve the production process and thus, increase a firm's effectiveness (Porter and Van der Linde, 1995). When a country introduces environmental regulations it leads to a cost for the firm which has to be evaluated against the benefits from environmental improvements. Costs that can be associated to the implementation of a new environmental regulation are; costs for new equipment, administration costs, production disruptions and a switch to more expensive input goods (direct costs). Other costs that may occur are losses of potential future profits (indirect costs). For example, if a firm undertakes an investment which in the long run would lead to a higher productivity than the one they are forced to invest in by regulations, they would lose potential higher profits. Some of the costs associated to an investment can also be "hidden costs", which means that they on the beforehand can be hard to detect and evaluate and thus, would be unexpected extra costs (Regeringen, 2007).

DeCanio (1997) expresses a relationship between environmental performance and competitiveness of a firm as the trade-off between environmental goods and non-environmental goods, where stricter regulations force a firm to produce more of the environmental good. It builds on the theory developed by Michael Porter and uses a production possibility frontier graph with environmental and non-environmental goods as outputs. In figure 5 down below it can be illustrated what effects regulations could have on firms.

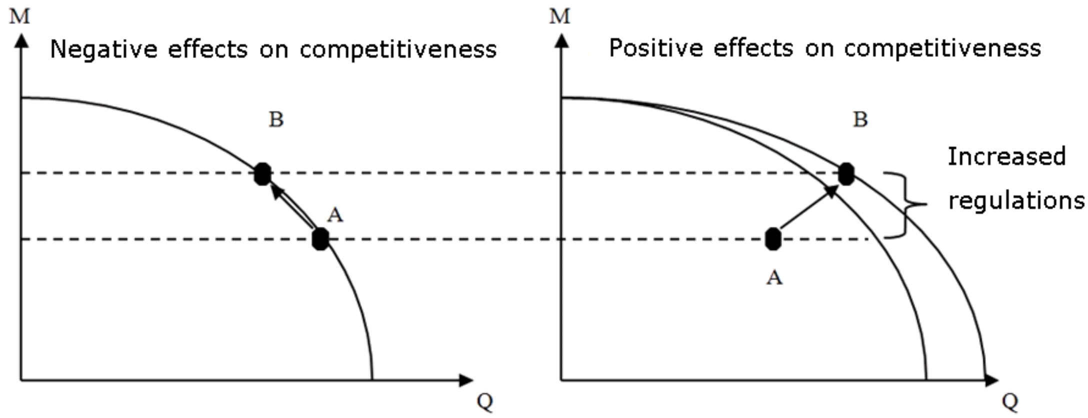

Figure 5: Effects of environmental regulations
Source: Söderblom (2012)

In the left diagram we can see how a firm moves from point A to point B due to an increase of environmental regulations, which forces the firm to lower their production of non-environmental goods (Q) and to increase the output of environmental goods (M). The right diagram in the figure on the other hand displays a case where the firm is not operating on an effective level (DeCanio, 1997). One reason for why a firm is not producing on an efficient level could be market barriers. Here Thollander and Ottosson (2008) summarize that most of the barriers for investments come from non-market failures, indicating that behavioral and organizational factors have a main role for a firm to operate on an effective level. Here informational failures can play an important role for environmental protection investments as well as behavioral failures. Informational failures can take form in several ways, for example it is costly to gain information, also it can be difficult to signal the benefits of the new technology to consumers (Jaffe and Stavins, 1994). Behavioral failures also play an important role for technology investments, a firm who acts under bounded rationality, meaning that they might rather choose investments under a "thumb-rule", could choose investments that are not an optimal choice. It is a possibility that firms overcome these failures due to an environmental regulation, forcing firms to increase its awareness about the production process. It could also force firms to invest more in information so to find new technologies. Continuing the argument framed by Michael Porter (1995); when a firm currently is operating on an inefficient level (point A in the right diagram of figure 5), an environmental regulation could increase the awareness within a firm and by investing in new technology a firm would switch upward to an efficient level equal to point B (the right diagram of figure 5). This is a positive side effect that environmental regulations could lead to. Even though environmental policies in many cases show a positive correlation to innovations, a firm's competitiveness also arise from technology push (ex. R&D expenditures) and market pull such as customer satisfaction (Refeld et al., 2007).

With the approach of the above theory and models, it can be summarized that firms have incentives to invest in environmental protection technologies for at least three reasons, firstly, because they want to improve their effectiveness, secondly, because of pressure from environmental policies, and third, to meet consumer preferences. Finally, barriers for investments arise from uncertainty and market failures, leading to an inefficient production level.

CHAPTER 4
METHOD AND DATA

In order to determine why firms choose to invest in abatement technologies an econometric model was used. Many of the previous studies have used the same method to find out what factors triggers firm to invest in new technologies. Since there were many zeros in the data sample a censored econometric model was used.

4.1 Data description and explanation

The data used was a panel data of industrial firms in Sweden for the time period 2004 to 2010. The data came from two sources, where specific firm details were collected by phone interviews which later were combined with complementary firm specific data taken from Statistics Sweden (SCB). All data are secondary data and were taken from a doctoral thesis by Mansikkasalo (2013). Originally the data used were collected with the purpose to examine why some firms are more energy intense than others, but since information about abatement investments and energy conservation investments were collected as well, the data could also be used for this purpose. Some weaknesses with the data to consider are that the answers are restricted to how the respondent understood the questions, meaning that depending on the knowledge of the respondent the data's validness could differ. Also, there exists a possibility of interviewer bias, where the data were dependent on how the interviewer chose to understand the respondents answer. An introduction to how the data was collected will be introduced in the section below, starting with explaining the phone interviews.

In order to find out why some firms are more energy intense than others the interview included questions that could give answer to decision-making practices within a firm, here information about how energy efficiency matters was communicated through the firms as well as the existence of hidden costs. The phone interviews were restricted to firms that had at least 200 employees who all belonged to one of six broad industry sectors of energy intense character. In total, 151 firms were found to fit within the restrictions and out of those 101 firms chose to participate in the interview. All of the questions in the interview were loosely constructed in order to not get answers of only yes or no. By using open questions it was possible to gain more detailed information about firms' incitement for investing in certain technologies. Firstly the interviewer started by asking an open question which then was followed by more specific questions related to the opening one. In order to avoid respondent bias some of the interview questions were scoring point from a scale one to five. Another bias that was considered were interviewer bias, which was tested for by letting a second participate conduct answers from 11 of the total 101 firms who participated. No significant bias could be found for the interviewers (Mansikkasalo 2013).

From the other data source (Swedish statistics) the data are collected by standardized questionnaires on annually basics. Weaknesses with that data are that the reported values are filled in by the company on its own, so one cannot be sure that the numbers are perfectly correct. Furthermore, since the questionnaire is sent out by mail it is also hard to know the knowledge the respondent have about the questions asked. Further details about the questions in the interviews can be seen in the sub-chapter "explanatory variables".

Again, since the data were originally meant to be used for another purpose than the purpose of this study, the collected data on abatement and energy conservation investments are not fully complete. Also some sample bias could exist which has to be kept in mind when analyzing the results. The independent variables included are output (Y), energy intensity (EUY), energy prices (Pave), hidden costs (HC), top management awareness (Tmaw) and research and development (R&D).

As dependent variables environmental protection investments will be used in three different models. The environmental protection investments have been divided into three categories; a) clean abatement technologies (MSI-extern), end-of-pipe solutions (MSI-intern) and energy conservation technologies (Energy conservation). These three are described in Statistics Sweden as the following:

- MSI-extern: Investments that does not affect the production process referred as end-of-pipe solutions (such as filters etc.) and thus, reduces emissions in the end of the production process.
- MSI-intern: Investments that are used to prevent pollutions with a change in the production process, for example by changing the input goods to cleaner goods or invest in better technology.
- Energy conservation: Investments in technology that directly saves energy and/or heat completely or partially.

The two first dependent variables will be compared with each other to see if there exists any difference between clean abatement technologies and end-of-pipe solutions, whiles the third variable will be used to see if there exists any crowding-out effect. In table 2 below some descriptive statistics on the dependent variables are displayed.

Table 2: Descriptive statistics of dependent variables (all values are in kSEK)

Dependent Variable	Mean	Standard deviation	Min	Max	Cases	Missing
Energy conservation	8 925	34 997	0	377 630	293	323
MSI-Extern	8 020	23 351	0	249 675	433	185
MSI-Intern	5 541	17 865	0	200 800	436	180

From the descriptive statistics displayed in this table we can see that firms make larger investments in Energy conservation technologies than in clean abatement technologies (MSI-intern) and end-of-pipe technologies (MSI-extern). The largest investment for energy conservation technologies was 377 630 kSEK whiles the largest for clean abatement technologies and end-of-pipe technologies were 249 675 kSEK and 200 800 kSEK respectively. What also can be seen is that for energy conservation investments there are most missing cases in the data sample compared to the other two dependent variables. In the following three figures (i.e., Figures 6-8) we can see the distribution of the dependent variables for the year 2010, sorted by lowest to highest.

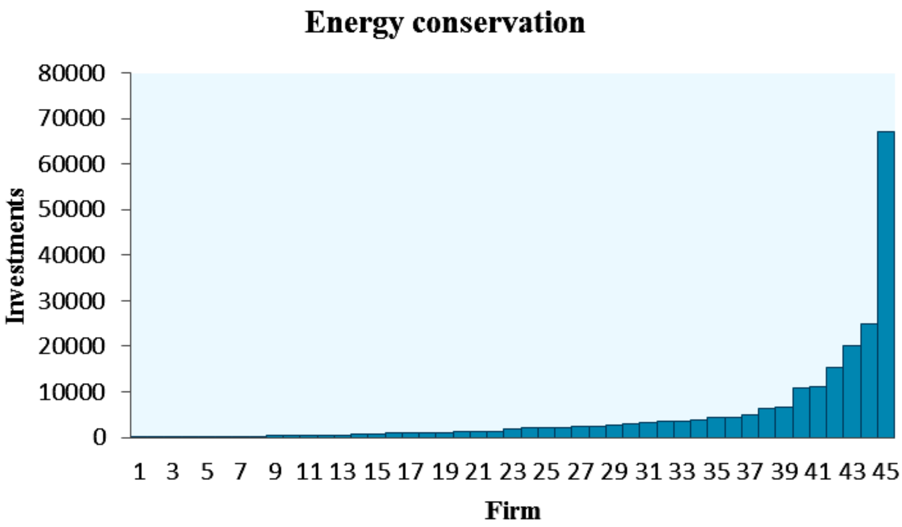

Figure 6: Energy conservation investments

Source: SCB

For the year 2010 there were 33 missing cases in the data sample for energy conservation investments. The lowest investment observed was 26 kSEK and the largest was 67071 kSEK. The mean value for this year was 4920,311 kSEK.

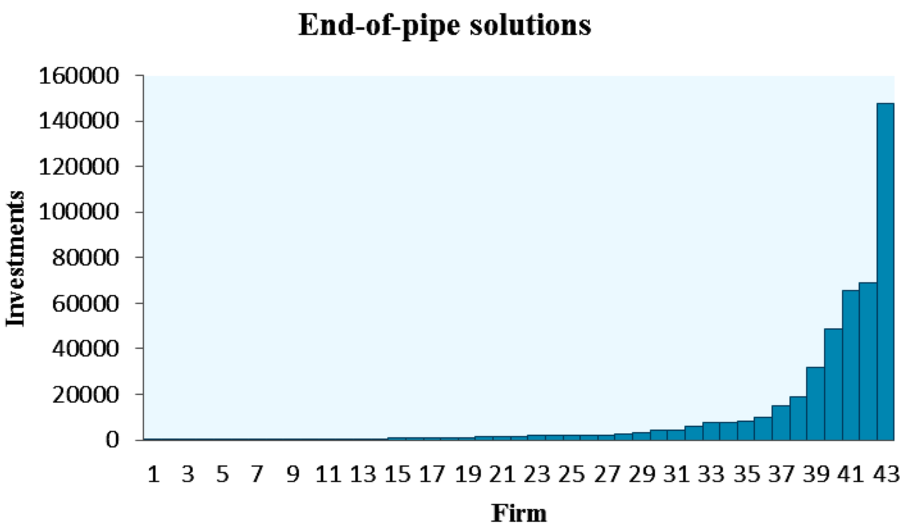

Figure 7: End-of-pipe technology investments

Source: SCB

For end-of-pipe technology investments there were 13 missing cases and 22 zeros reported. The lowest investment (except zero) was 46 kSEK and the largest investment was 147 569 kSEK, the mean value was 7262,8 kSEK.

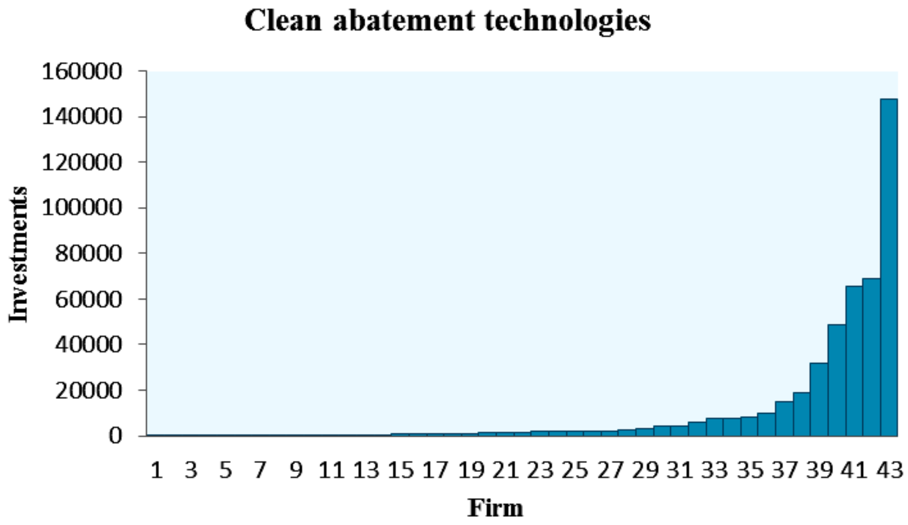

Figure 8: Clean abatement technology investments
Source: SCB

For clean abatement technology investments there were 13 missing cases and a total of 30 zeros reported. The lowest investment (except zero) was 8 kSEK and the largest investment was 256000 kSEK, the mean value was 12576,18 kSEK. In the following section the independent variables will be described.

4.2 Explanatory variables

In this section the independent variables which are included have been described. A correlation matrix was run to see how the variables were correlated to each other (see appendix 1), and variables with a correlation higher than 0.5 were excluded. Four variables showed a correlation higher than 0.5, which were labor costs and total output, awareness and top management awareness. Therefore, only total output and top management awareness have been included in the models.

4.2.2 Firm characteristics

To test if certain firm characteristics matter an energy intensity variable was used, this variable was created by dividing the total yearly energy use by the total yearly output of the firm (Mansikkasalo 2013). It is reasonable that firms with a higher total energy cost are more willing to invest in more effective technologies, so to lower their costs and raise their profits. Data on energy use and total output was collected from Statistics Sweden and by meaning, as mentioned earlier; there exist some weaknesses with that data. For example since the firms' by themselves fill in the answers in the questionnaire the reliability of the values are uncertain. However, since the same holds for the whole sample we can assume it to work as a good measurement for energy costs. In the figure below we can see the range of energy intensity between firms' from the data sample. The values are only from the year 2010 for each firm and are sorted by lowest to highest to keep the overview as simple as possible.

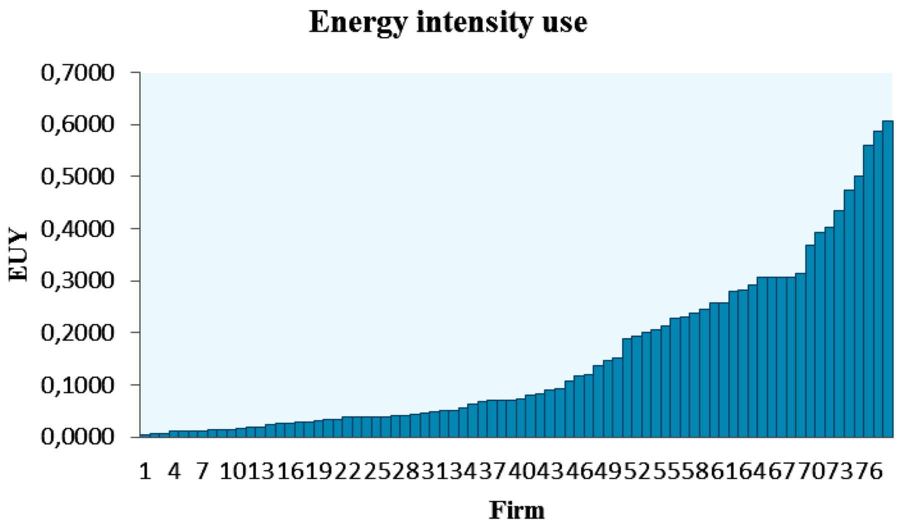

Figure 9: Energy intensity use (MWh/kSEK)

Source: Mansikkasalo (2013)

It is clearly in the figure above that energy intensity use is widely spread among firms, for the year 2010 the lowest value observed was 0.0041 and the highest 0.6058, with a mean value of 0.1497 (all values are in MWh/kSEK).

Also total yearly output (y) was included in order to see if the size of a firm matters. It is reasonable to assume that larger firms have a higher capacity and more resources to invest in abatement and energy conservation technologies. Of course, there are other ways of measuring the size of a firm (e.g. number of employees, profit etc.), but for this study the use of yearly output was best suited as a size variable considering the given data of hand. However, the reliability for this variable is also debatable since it too comes from the questionnaire by Statistics Sweden's, and the same weaknesses holds for this variable as the previous. In the figure below we can again see the spread among firms, same as previous; all values are from the year 2010 and are sorted by lowest to highest.

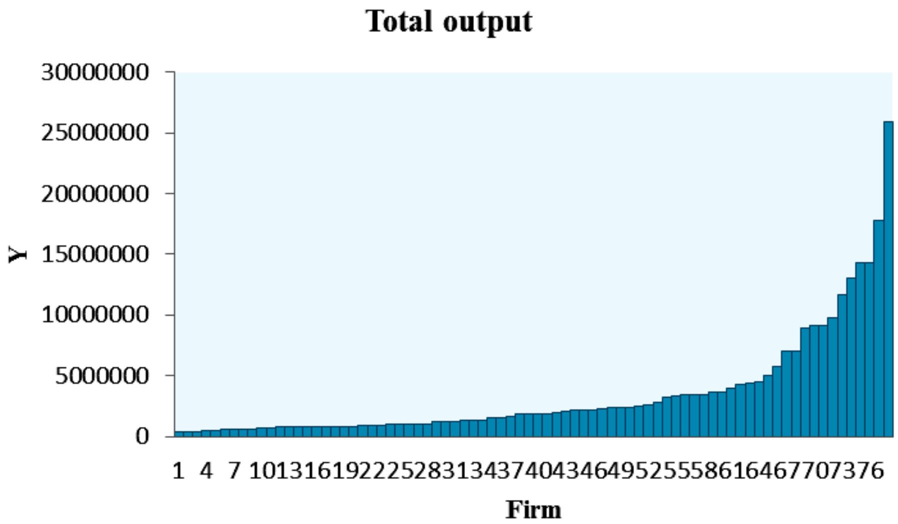

Figure 10: Total output (kSEK)
Source: SCB

Total output among firms for year 2010 seems to be less spread than for energy intensity use, here the lowest value was 353 655 kSEK and the highest was 25 936 548 kSEK, with a mean value of 3440591 kSEK.

4.2.2 Top management awareness

Top management awareness (Tmaw) has been included as an independent variable for this study. This variable intends to see if organization behavioral affects investments in abatement and energy conservation technologies. It can be argued that firms with a top management that finds energy efficiency as an important role for the firm are also more likely to be aware about the production process and available technologies on the market. The data for top management awareness comes from the phone interviews, where open questions about the importance of energy efficiency were asked. The respondent was given a score from 1-5, where a score of 1 implied “no top management awareness”, 2 or 3 implied that questions about energy efficiency were only discussed occasionally and finally, a score of 4 or 5 indicated that questions like that were discussed continuously (Mansikkasalo 2013). Since the questions were simply about energy efficiency it should carefully be interpreted with the results for the two types of abatement technologies. It is possible that the results would be different if questions about “how important the environment is” etc. were asked. It could still be interesting to see how big role the top management seems to have in a firm, however, the estimated values should not be taken too truly. In the figure below we can see the frequency between the scores for the year 2010.

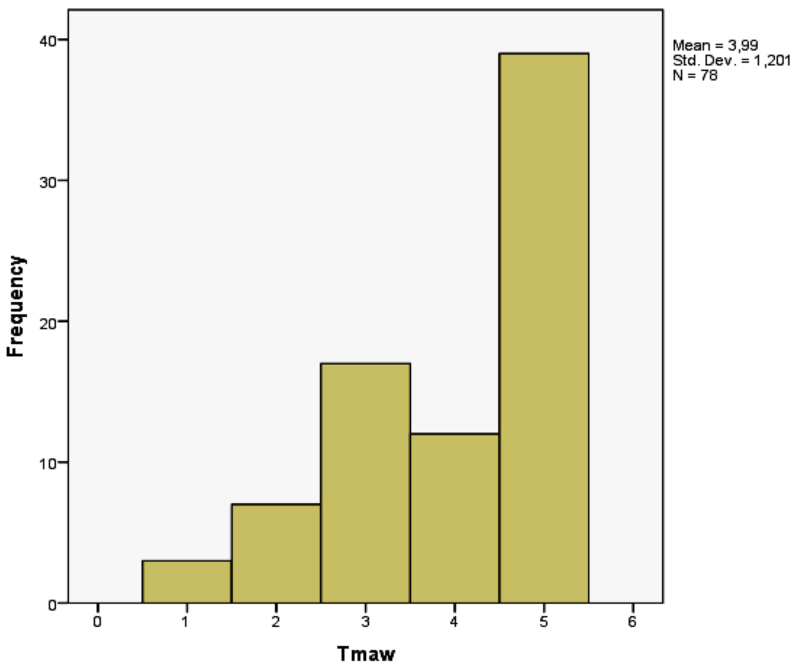

Figure 11: Top Management Awareness Scores
Source: Mansikkasalo (2013)

As we can see in the histogram the mean value are quite high, and for the year 2010 top management awareness had a mean score of nearly 4. Compared to the mean value with all years included, (see table 3: descriptive statistics of the independent variables) the mean value of 2010 is higher. This could mean that top management awareness has increased during the years.

4.2.3 Input prices

Energy prices are used as an input price variable in the models. The energy prices were calculated as the yearly average price and data on this was taken from Statistics Sweden (SCB). Since earlier studies have found that energy prices affect the probability of energy conservation investments (e.g. Pizer et al., 2002), it could also have an impact on abatement technology investments (Hammar and Löfgren, 2010). There are other variables that could have been used as input prices (for example material costs). However, it could be rather hard to compare data on material costs since the use of material differs between branches. Therefore, energy prices are most suited as an input price variable. In the figure below we can see the spread of energy prices between firms'. Here as earlier, we have energy prices for the year 2010 sorted by lowest to highest.

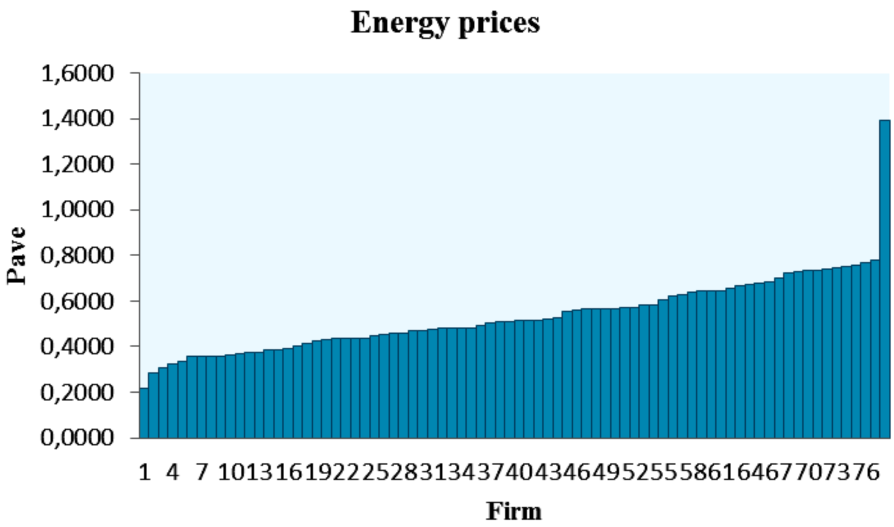

Figure 12: Energy prices (kSEK/MWh)

Source: SCB

For the year 2010 the lowest energy price observed was 0.2158 and the highest was 1.3949, with a mean energy price of 0.535 (all values are in kSEK/MWh).

4.2.4 Hidden costs

Uncertainty has been found to have a negative effect on investments (e.g. Löfgren et al., 2008), so in these three econometric models "hidden costs" will be included as an independent variable. Here hidden costs are referred as a cost that is not included in the evaluation of an investment but still is related to the investment. The question in the phone interview for hidden costs was formulated as the following:

> "Are there any other costs, besides those directly related to the investment, that are taken into account when considering a potential energy efficiency investment? For instance, (a) the costs of production disruptions?; (b) the costs of hiring new staff/retraining the existing one?; and/or (c) the costs for identifying the opportunities; analyze their costs and the costs of procurement?" (Mansikkasalo, 2013, p. 17).

If the respondent could not give any example or only a few examples, the score of 1 or 2 was given. With a score of 3 the respondent implied that hidden costs prevailed occasionally. Finally, a score of 4 or 5 was given when the respondent could give specific examples of such costs (Mansikkasalo, 2013). When collecting the data for this variable it should be kept in mind that depending on the respondents' knowledge about investment evaluations and its costs associated to it, the validness about hidden costs can differ between firms'. However, since uncertainty seems to have a negative impact on investments it should be tested for, and it could be argued that higher hidden costs makes firms' to more often avoid investing in new. In the figure below we can see the frequency between the scores for the year 2010.

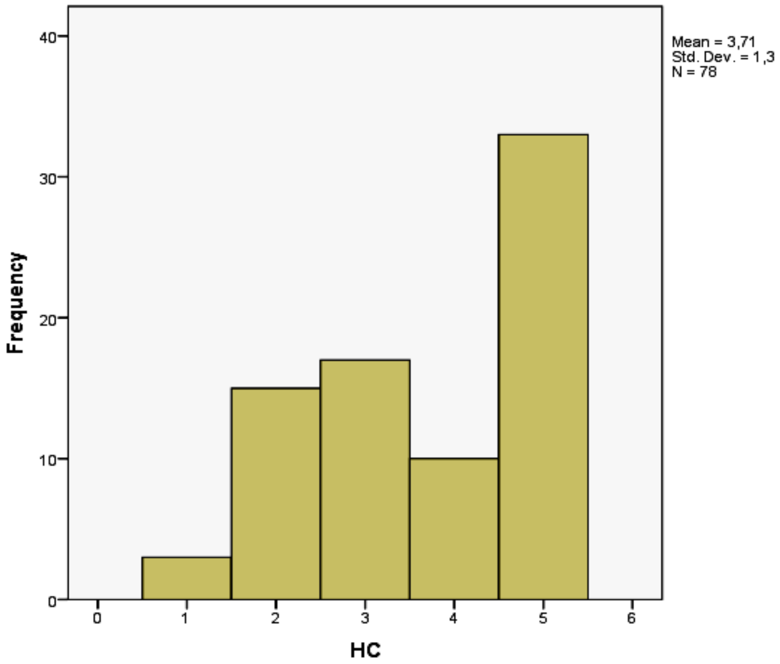

Figure 13: Importance of hidden costs (self-reported scores)

Source: Mansikkasalo (2013)

The histogram reveals that hidden costs are quite high for investments; the mean value for the year 2010 was 3.71 in score ranking.

4.2.5 Research and development

Finally, research and development (R&D) will be included since most previous studies have found that research and development expenditures are important for boosting innovations and technology development. The data for R&D has been collected from Statistics Sweden (SCB). The same argument about its validness goes as for firm characteristics variables (see section 4.2.2.), which is that firms by themselves fill in the questionnaire and gives the amount of expenditures for R&D and thus, the numbers might not be the true values.

Hammar and Löfgren (2010) says that R&D can be seen as knowledge and learning. The argument following by this is that firms with higher R&D expenditures have a better understanding on how to use new technologies and that they are also likely to be updated with existing available technologies. A better knowledge could by that meaning have a positive effect on firm’s willingness to invest in abatement technologies. In previous studies the results have shown that R&D does have a positive effect, but that this effect differs between the two types of abatement technologies (clean abatement and end-of-pipe solutions). The effect it has on energy conservation investments will also be tested for in this study. In the figure below we can see the spread in R&D expenditures among firms' for the year 2010. Firms who were not able to report their expenditures in R&D for this year have been excluded.

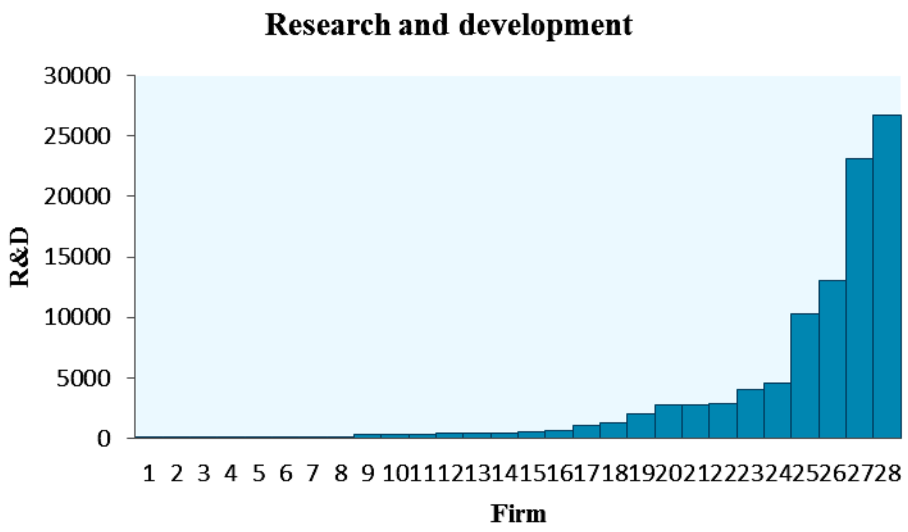

Figure 14: R&D expenditures (kSEK)
Source: SCB

Out of the 78 firms' it were 65 who were able to report their expenditures in R&D. 37 firms reported zero expenditures in R&D for the year 2010 and the overall mean value was 1520,046 kSEK. The lowest reported expenditure was 14 kSEK (except for zero) and the highest 26718 kSEK. It can also be seen that it is widely spread between the lowest and highest R&D expenditures between firms.

All independent variables that have been used are motivated by theoretical assumptions and earlier studies findings. Since the data available for this study was limited it was not possible to include some variables that might have been desirable. Down below follows a table with descriptive statistics of the independent variables used in the regression models.

Table 3: Descriptive statistics of the independent variables

Descriptive Variable	Definition	Mean	Std.Dev	Min	Max
Output (Y)	Gross output (kSEK)	309 035	393 667	125 115	2 593 650
Energy intensity (EUY)	Energy use (MWh) divided by Output(kSEK)	0.180	0.216	0.011	1.651
Energy price (PAVE)	Average energy price (kSEK/MWh)	0.442	0.158	0.137	2.191
Top management awareness (TMAW)	Top management awareness of energy efficiency ranking values 10-50	35	15	10	50
Hidden costs (HC)	Hidden costs in ranking values 10-50	36	13	10	50
Green research and development (GRNFOU)	Expenditures in green R&D (kSEK)	1 363	5 975	0	98 000

As can be seen in the table above the mean size of a firm (in matters of gross output) is 309 035kSEK, whereas the smallest and largest gross output were 125 115kSEK and 2 593 650kSEK respectively (wide range between smallest and largest firm). The mean energy intensity value was 0.18MWh/kSEK, where the most energy intense firm ended up to 1.661MWh/kSEK. The mean value for energy prices were 0.442kSEK/MWh with prices that lies between 0.137-2.191kSEK/MWh. Top management awareness of energy efficiency had a mean value equal to 35 (ranking between 10-50) and hidden costs with a mean value of 36 (ranking 10-50). Expenditures for green research and development had a mean value of 1 363kSEK where the highest amount of expenditures was 98 000kSEK. Compared to the descriptive statistics on the dependent variables (see table 2), expenditures paid for green R&D are a lot less than what is paid for investments in clean abatement technologies, end-of-pipe solutions and energy conservation technologies.

4.3 Model specification

The choice of econometric model was decided with consideration to the large amount of zeros included in the data sample. Normally when using a linear regression model the Ordinary Least Square (OLS) often is used. However, when a data sample includes many zeros it can make estimated values biased and inefficient if one choses to use a normal OLS-model. An alternative regression model was the Tobit-model; and this regression model is preferable when dealing with a large number of zeros. This type of model is called a censored regression model and was first developed by James Tobin in 1958. This model has the advantage to deal with cross sectional data sets where the sample has missing data or where the values of the dependent variable includes many zeros (Wilson and Tisdell, 2002).

4.3.1 The Tobit model

To explain how the Tobit model works with missing data or a number of zeros in the observed values the following relationship can be expressed:

$$Y^* = \beta_1 + \beta_2 X + u_1$$

In this equation Y stands for the dependent variable, β_1 is the constant, β_2 is the estimated values from the observed independent values, X stands for the observed values of the independent variable and u_1 is the error term. Furthermore, the dependent variable (Y) can be subjected to either a lower bound (Y_L) or an upper bound (Y_U). For example if the case of a lower bound is used, it can be written as:

$$Y^* = \beta_1 + \beta_2 X + u_1$$
$$Y = Y^* \text{ for } Y^* > Y_L,$$
$$Y = Y_L \text{ for } Y^* \leq Y_L$$

The same holds for a case where an upper bound is used instead. For the data set that is used in this study the case of a lower bound occurs. Here the lower bound is equal to zero ($Y_L = 0$). With this use of a censored regression model the estimated values and the intercept will be more correct (Dougherty, 2007).

4.3.2 Model specifications

For this study three regression models have been used, where the dependent variable differs whiles the independent variables holds constant. For the first model Energy conservation will be used as dependent variable and for the two following MSI-extern and MSI-intern will be used.

Model 1 - with energy conservation as dependent variable:

$$\text{Energy conservation}_{it} = \alpha + \beta_1 Y_{it} + \beta_2 EUY_{it} + \beta_3 Pave_{it} + \beta_4 Tmaw_{it} + \beta_5 HC_{it} + \beta_6 FoU_{it} + \varepsilon_{it}$$

Model 2 - MSI-extern as dependent variable:

$$\text{MSI-extern}_{it} = \alpha + \beta_1 Y_{it} + \beta_2 EUY_{it} + \beta_3 Pave_{it} + \beta_4 Tmaw_{it} + \beta_5 HC_{it} + \beta_6 FoU_{it} + \varepsilon_{it}$$

Model 3 - MSI-intern as dependent variable:

$$\text{MSI-intern}_{it} = \alpha + \beta_1 Y_{it} + \beta_2 EUY_{it} + \beta_3 Pave_{it} + \beta_4 Tmaw_{it} + \beta_5 HC_{it} + \beta_6 FoU_{it} + \varepsilon_{it}$$

Here i stands for the specific firm whiles t stands for the time period. Y stands for total output, EUY stands for energy intensity use and Pave for the average energy price. Tmaw refers to top management awareness. HC in the model stands for hidden costs and Green R&D expenditures is denoted as FoU, while ε stands for the disturbance variable. This linear regression model will provide information about the degree the independent variables included affects the dependent variables.

4.3.3 Test for fixed effects

All three models were tested for fixed effects with the help of a log likelihood ratio test. The log likelihood ratio test is a test that compares two models with each other in order to see which model is the most fitted one. The null hypothesis indicates that the extra variables included have no explanatory value. The formula for the test is the following:

$$Df = df2\text{-}df1;\ 2*(L\text{-}L_0)$$

Where Df2 = degrees of freedom for the alternative model and Df1 is the degrees of freedom for the null model (the models without any dummies in this case). L stands for the log likelihood value for the null model and L0 stands for the log likelihood value for the alternative model, and “2” is a constant. The alternative models included both branch dummies and year dummies. The test was insignificant on all significance levels (see appendix 2) and thus, the null hypothesis could not be rejected. So when including dummy variables it could not be sure to add any extra explanatory value (Dougherty, 2007) and they were therefore excluded.

CHAPTER 5
RESULTS AND ANALYSES

In this chapter the results from the regression have been presented and analyzed. The first section concludes a technical presentation of the results while the second section discusses and analyzes the results.

5.1 Results from the econometric models

From the regressions it is clear that there are some differences between clean abatement technologies, end-of-pipe solutions and energy conservation investments. As what can be seen the results differ in both size of coefficients and the significance level. Some of the results are consistent with the results from previous studies; however some of the results do not follow what have been found earlier nor does it show what is expected from theory. The tables displayed in this section show the estimated parameters and their corresponding t-values. Most of the results were to be expected but unfortunately many of the coefficients were not significant. Even when including a branch dummy or a year dummy (or both) the results did not differ much in significance level. Furthermore, with a likelihood test it was found that it is not motivated to include any dummies (see section 4.3.3 and appendix 2). In the results the most surprisingly finding was that energy prices have a negative effect on investments, which was not expected at all since a higher price should lead to a drive to invest in more efficient technologies.

The first table displays the results from the first model, where energy conservation investments have been used as the dependent variable. The second table shows the results from model 2 where end-of-pipe technology investments were used while the third table shows the results from the model where clean abatement investments was used as the dependent variable.

Table 4: Results from Model 1 – energy conservation

			Model I
Independent variables	**Coefficients**	**t-ratios**	**P [T] > t-ratio**
Output (Y)	*0.0017	3.650	0.000
Energy intensity (EUY)	*20 350	2.760	0.006
Average energy price (Pave)	*-17 700	-2.413	0.016
Top management awareness (Tmaw)	15.763	0.105	0.916
Hidden costs (HC)	206.63	1.356	0.175
Research and development (GrnFoU)	-0.8736	-1.268	0.205
			Log-likelihood: -3392.648

Coefficients with an asterisk are statistically significant at the 1% level

In model 1 where Energy conservation is used as the dependent variable the result shows that output (Y) is positive correlated and significant, but have a very low coefficient (if output increases with 1 kSEK an increase in investments of energy conservation technologies increases with 0.0017 kSEK). Also energy intensity use was positive, with a coefficient of 20 350 meaning that an increase in energy intensity with 1 MWh increases the expenditures for investments with 20 350 kSEK. These two results were expected, since it has been argued that a larger firm indicates higher capacity, which should give a higher probability of investments. Further on, the energy prices had a negative impact on energy conservation investments; an increase in energy prices of 1 kSEK/MWh gives a decrease in investments with 17 700 kSEK. This result is very surprising since it is assumed that increasing energy prices should have a positive effect on firms' investments in energy conservation technology, in order to decrease their total energy costs. Top management, hidden costs and research and development all had positive coefficients but the estimated values were not significant. Since uncertainty have shown to have a negative effect on investments it was not expected that hidden costs would have a positive effect (hidden costs have been argued to me connected with uncertainty).

Table 5: Results from Model 2 – MSI-extern

			Model II
Independent variables	**Coefficients**	**t-ratios**	**P [T] > t-ratio**
Output (Y)	*0.0024	9.953	0.000
Energy intensity (EUY)	*31 691	6.646	0.000
Average energy price (Pave)	*-29 865	-6.280	0.000
Top management awareness (Tmaw)	*277.29	2.490	0.013
Hidden costs (HC)	*-200.23	-1.998	0.046
Research and development (GrnFoU)	0.0998	0.488	0.626
			Log-likelihood: -3541.509

Coefficients with an asterisk are statistically significant at the 1% level

The results from Model 2 where end-of-pipe solutions (MSI-extern) were used as dependent variable, showed that output is significant and positive correlated to end-of-pipe technology investments. However, the coefficient is also in this model very small, an increase in gross output of 1 kSEK increases investments by 0.0024 kSEK. Energy intensity was positive correlated and significant with a coefficient of nearly 32 000, which means that an increase in energy intensity of 1 MWh increases investments with 31 691 kSEK. Same as in the results from model 1, these results are to be expected. The energy price was negative correlated to investments and were also significant, which still is a very surprisingly result. This indicates that when energy prices increases by 1 kSEK/MWh, investments in end-of-pipe solutions decreases with 29 865 kSEK. In this model Top management awareness was significant and positive, where a higher degree of awareness leads to increased investments with almost 277 kSEK. Hidden costs were also significant in this model and had a negative impact on firms' investments in abatement technologies, which was expected. A higher score of hidden costs leads to a decrease in investments by nearly 200 kSEK. Green research and development was positive but not statistically significant for investments in end-of-pipe solutions.

Table 6: Results from Model 3 – MSI-intern

			Model III
Independent variables	**Coefficients**	**t-ratios**	**P [T] > t-ratio**
Output (Y)	*0.0015	5.337	0.000
Energy intensity (EUY)	*14 073	3.024	0.03
Average energy price (Pave)	*-13 385	-2.875	0.04
Top management awareness (Tmaw)	113.23	1.339	0.181
Hidden costs (HC)	67.328	0.701	0.483
Research and development (GrnFoU)	0.1528	0.819	0.413
			Log-likelihood: -3127.377

Coefficients with an asterisk are statistically significant at the 1% level

The results from model 3 where clean abatement investments (MSI-intern) was used as the dependent variable it was found that Output (Y), energy intensity (EUY) and energy prices (PAVE) were all significant, same results as in the two previous models. The results show that when gross output increases by 1 kSEK, investments in clean abatement technologies increase by 0.0015 kSEK. Energy intensity use had a positive effect on investments in clean abatement technologies with a coefficient of 14 073. Both output and energy intensity were expected to be positive. The energy prices on the other hand also here had a negative effect on investments, an increase in energy prices by 1 kSEK/MWh leads to a decrease in investments by 13 385 kSEK. The three following variables, top management awareness (Tmaw), Hidden costs (HC) and research and development (GrnFoU) were all positive correlated, but not significant (same results as for model 1). It was expected that top management awareness, green research and development would have a positive effect, however, it was not expected that also hidden costs would have a positive effect on investments.

5.2 Analysis of results

As could be seen in the results firm characteristics such as size (in matters of gross output) and energy intensity use were significant and that they had a positive effect on investments, which holds true for all three models. These results were somewhat expected since a larger firm should have a higher capacity and thus, are more likely to do investments. These results have also been found in several previous studies, which have been summarized in this study (see Frondel et al., 2011; Löfgren et al., 2013). In the study made by Löfgren et al. (2013) they concluded that firm characteristics are indeed of importance for a firm's probability to invest in technologies. The most unexpected and surprising result found here, was that energy prices have a negative impact on investments, which was true for all the regression models. From previous studies that has been summarized this result have not been found. It is very illogical that higher energy prices should have such a negative impact on investments that these results showed. The reason for this could be that the data sample that was used contained only of firms who are energy intensive, and thus, these results could come from the existence of a sample bias. Another possible explanation could be that for firms who are already energy intense, a higher energy price causes a crowding-out effect in that firms chooses to focus on lowering their energy use so to lower their costs instead of investing in abatement technologies. This argument does however not hold true for the results in model 1, where energy conservation investments was used as the dependent variable. So it is possible that it arises because of problems with data set (e.g. lot of missing cases for the dependent variables, many zeros etc.).

Top management awareness and hidden costs were only significant for model 2, where end-of-pipe solutions (MSI-extern) were used as dependent variable. Here top management awareness had a positive impact on investments in end-of-pipe solutions, and hidden costs had a negative impact. The results for top management awareness can be explained to as a firm with a top management who are more aware about energy efficiency also are more likely to discuss alternative investments that could lower the energy use. If energy efficiency is discussed more often within a firm, it is also likely that the firm is better updated on available technologies that are more efficient than the current ones. The results for hidden costs in model 2 are reasonable, where hidden costs had a negative effect on investments. If an investment give arise to higher costs than expected, it makes the investment less profitable. For the other two models hidden costs showed a positive coefficient (model 1 and 3), which is not logical. However, these results were not significant and thus, should not be taken too seriously. The result in model 2, where hidden costs had a negative effect on investments, is comparable to the study made by Löfgren et al. (2008) where they found that uncertainty have a negative effect on firms' investment decisions. It can be argued here that when uncertainty about costs increases, firms avoid taking investment decisions because the expected benefits for an investment would be lower when the costs associated to it are higher.

Surprisingly it also seemed that green research and development had no significant effect on environmental protection investments in any of the tested models. However, the coefficients were still positive and as it has been argued for earlier, a firm with higher R&D expenditures should (at least) in theory be more likely to invest in new technologies. The reason for no significant results could be that the data sample's time period was too short, and/or that overall the expenditures paid for green research and development were relatively small. In the study by Löfgren et al. (2013) the results were the same, green R&D had no clear evidence of significant results. Even if green R&D was not significant they still found that earlier investments (considered as "learning by doing", which also green R&D could be considered as) had a positive and significant effect on investments. Unfortunately, this kind of data was not available for this study. It could have been interesting to see if earlier investments would have an effect on investments.

The results would probably be better with the use of a more complete data set. For example, the data drawn from the phone interviews could have been complemented with information about environmental protection investments and how those decisions are discussed within the firm. Moreover, the choice of firms included in the data sample should maybe not have been limited to firms of energy intense characters. Furthermore, it would also be preferable to have a longer time period and/or comparing two time periods.

CHAPTER 6
CONCLUDING REMARKS

The main purpose of this study was to determine firms' investments in abatement technologies with a sub-purpose to see if any crowding-out effect existed between energy conservation investments and abatement technology investments. Since this area has been widely researched in before, there are many results of what is supposed to have an impact on firms' decision to invest. However, the results have been spread and it is still important to do further research in this area. Also, there have been very little research in the existence of crowding out effect between energy conservation investments and abatement technology investments. In order to examine the purpose of this study a data sample that consisted of 78 Swedish firms was used. The data sample included firm characteristics variables such as firm size (in matters of gross output) and energy intensity. Other variables that were included were hidden costs, top management awareness, energy prices and green R&D. The data sample included a lot of missing cases and also many zeros; therefore a censoring regression model was used. Since the data set that was used had a lot of missing cases and zeros, and that the purpose for what it was collected for was different, one must be careful with how reliable the results are.

The main findings were that firm characteristics are of importance for types of investments. Here the size of a firm had a positive effect on abatement technology investments and energy conservation investments. Also the energy intensity use for a firm increased investments. Other variables that seemed to have an effect on investments were hidden costs and top management awareness. However, these results were only significant for end-of-pipe solutions (model 2). As could be found in the study made by Hammar and Löfgren (2011) was that the drives for investments differ between the two types of abatement technologies. Secondly, the results for energy prices that was found (energy prices have a negative effect on investments) could indicate that there exist some kind of crowding-out effect between energy conservation investments and abatement technology investments. Because energy prices had a negative impact on investments it could imply that firms choses to invest in energy conservation technologies rather than investing in abatement technologies. However, this must be considered carefully since the same result was found for model 1 where energy conservation investments were used as the dependent variable.

It is interesting to see that there might exist a crowding-out effect between energy conservation and abatement technology investments. If this is true policy makers need to take this in account when forming their environmental policies. Even though the result indicates the possibility of an existing crowding-out effect, this conclusion cannot be drawn with certainty, and thus, future researches in the area should be made. It must also be kept in mind that the possible existence of a crowding out effect is not entirely negative, since energy use is strongly associated to emissions. So by lowering the energy use it will also lower the total output of emissions. Finally, since the data sample that have been used in this study consisted of only energy intense firms the results cannot be said to hold true for all Swedish firms in general.

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APPENDIX 1
CORRELATION MATRIX

Down below a table is displayed over the correlation between the explanatory variables. A correlation higher than 0.5 was considered to be too high, and thus, was excluded. Here Labor and Awareness was chosen to not be included since the correlation between labor and output, firm awareness and top management awareness was too high. Remaining variables for the models were output (Y), energy intensity (EUY), energy price (PAVE), top management awareness (TMAW), hidden costs (HC) and green research and development (GRNFOU).

	L	**Y**	**EUY**	**PAVE**	**AWARE**	**TMAW**	**HC**	**GRNFOU**
L	1	0.81	0.09	-0.17	-0.09	0.01	0.06	0.08
Y	0.81	1	0.20	-0.26	-0.01	0.04	0.17	0.17
EUY	0.09	0.20	1	-0.42	0.04	0.15	0.08	-0.05
PAVE	-017	-0.26	-0.42	1	0.24	0.06	-0.05	-0.07
AWARE	-0.09	-0.01	0.04	0.24	1	0.75	0.23	0.09
TMAW	0.01	0.04	0.15	0.06	0.75	1	0.17	0.09
HC	0.06	0.17	0.08	-0.05	0.23	0.17	1	0.07
GRNFOU	0.08	0.17	-0.05	-0.07	0.09	0.09	0.07	1

APPENDIX 2
LIKELIHOOD TEST

Likelihood ratio test - energy conservation with/without year and branch dummies

Df2=18, Df1=7, L=-3392.648, L0=-3384.551:

- ➔ 2*(3392.648 - 3384.551)=2*8.097= 16.194

Significance level 0.1% critical value Df(11) = 31.26

16.194 < 31 => cannot reject null hypothesis

Likelihood ratio test – extern with/without year and branch dummies

Df2=18, Df1=7, L=-3541.509, L0=-3532.954

- ➔ 2*(3541.509-3532.952)=2*8.557=17.114

Significance level 0.1% critical value = 31.26

17.114 < 31 => cannot reject null hypothesis

Likelihood ratio test – intern with/without year and branch dummies

Df2=18, Df1=7, L= -3127.377, L0= -3118.941

- ➔ 2*(3127.377-3118.941) = 2*8.436=16.872

Significance level 0.1% critical value = 31.26

16.872 < 31 => cannot reject null hypothesis

APPENDIX 3
TESTED REGRESSIONS MODELS

Down below in the tables the differences in significance levels between the models with dummies and without dummies are displayed. As the log likelihood test showed there is no motivation for including any dummies in the models and thus, they are therefore excluded.

Comparison of regressions with and without dummies for energy conservation

Variable	**Without dummy**	**Bransch dummy**	**Year dummy**	**Bransch and year dummy**
Output (Y)	3.650	4.003	3.998	4.386
Energy intensity (EUY)	2.760	2.812	2.609	2.341
Average energy price (Pave)	-2.413	-1.392	-0.014	0.117
Top management awareness (Tmaw)	0.105	0.198	1.027	1.249
Hidden costs (HC)	1.356	1.378	1.615	1.665
Research and development (GrnFoU)	-1.268	-1.272	-1.478	-1.628
Log-likelihood	-3392.648	-3389.028	-3388.412	-3384.551

Comparison of regressions with and without dummies for MSI-extern

Variable	Without dummy	Bransch dummy	Year dummy	Bransch and year dummy
Output (Y)	7.953	8.357	8.058	8.496
Energy intensity (EUY)	6.646	4.500	4.510	4.495
Average energy price (Pave)	-6.280	-4.362	-2.439	-2.323
Top management awareness (Tmaw)	2.490	2.182	2.938	2.704
Hidden costs (HC)	1.998	-2.194	-2.008	-2.145
Research and development (GrnFoU)	0.488	0.766	0.688	0.923
Log-likelihood	-3541.509	-3535.223	-3539.318	-3532.954

Comparison of regressions with and without dummies for MSI-intern

Variable	Without dummy	Bransch dummy	Year dummy	Bransch and year dummy
Output (Y)	5.337	5.813	5.130	5.678
Energy intensity (EUY)	3.024	1.430	2.000	1.404
Average energy price (Pave)	-2.875	-2.413	-1.870	-2.117
Top management awareness (Tmaw)	1.339	1.308	0.705	0.678
Hidden costs (HC)	0.701	0.772	0.858	0.998
Research and development (GrnFoU)	0.819	1.102	0.744	0.998
Log-likelihood	-3127.377	-3123.221	-3123.715	-3118.941