

Determinants of Environmental Expenditure and Investment: Evidence from Sweden

Jūrate Jaraitė¹, Andrius Kažukauskas¹ & Tommy Lundgren²

¹Centre for Environmental and Resource Economics and Dept of Economics
University of Umeå
S-901 87 Umeå, Sweden

²Centre for Environmental and Resource Economics and Dept of Forest Economics
Swedish University of Agricultural Sciences
S-901 83 Umeå, Sweden

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Jūrate Jaraitė^{a,b}
Andrius Kažukauskas^{a,b}
Tommy Lundgren^{a,c}

^aCentre for Environmental and Resource Economics
SE-90187, Umeå, Sweden

^bSchool of Business and Economics, Umeå University
SE-90183, Umeå, Sweden

^cDepartment of Forest Economics, Swedish University of Agricultural Sciences
SE-90187, Umeå, Sweden.

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Abstract

This paper provides new evidence on the determinants of environmental expenditure and investment. Also, by employing the Heckman selection models, we study how environmental expenditure and investment by Swedish industrial firms responded to the national and international policies directed to mitigate air pollution during the period 1999 through 2008. We find that firms that use carbon intensive fuels such as oil and gas are more likely to spend to and invest in the environment. Larger, more profitable and more energy intensive firms are more likely to incur environmental expenditure/investment. Overall, an important finding of our econometric analysis is that environmental regulation both on the national and international levels are highly relevant motivations for environmental expenditure and investment.

Keywords: environmental expenditure and investment, environmental policy, EU ETS, panel data

1. Introduction

Sweden has been a leader in protecting its environment through introducing new legislation, stepping up enforcement, and encouraging community involvement to promote an environment-friendly culture. In the last two decades, the particular focus has been on mitigating air pollution in industry. Apart from traditional energy/excise taxes levied on energy products in the early 1990s, the Swedish government introduced CO₂ taxes (1991), SO₂ taxes (1991), and a NO_x charge (1992). Sweden, being the member of the European Union, is also subject to the European regulation, in particular, to the European Union's Emission Trading System (2005). Due to these regulations on the national and international levels the emissions of CO₂, SO₂, and NO_x have significantly decreased since 1990.

As abatement cost increases with the stringency of environmental policy, regulation has most certainly been a large factor in driving changes in production processes and investments to mitigate pollution. Unregulated firms may also decide to acquire and install less polluting capital technology equipment if it lowers their production cost. In addition, the fact that more firms integrate social, environmental and economic concerns into their values and operations and consumers becoming "greener" are likely to be another contributing factor.

Given the significant regulatory burden on firms to abate pollution and the resultant costs in Sweden, it is natural to wonder whether corporate environmental expenditure and investment is a response to these pressures or to other factors. Therefore the main goal of this paper is to explore the determinants of environmental expenditure and investment in the entire manufacturing sector in Sweden during the period 1999-2008. The available dataset allows us to examine several types of environmental expenditure: first we look at firm's current expenditure for environmental protection which includes all other costs of environmental protection that are not considered to be investment, second we consider firm's investment in environmental protection, and finally we analyse current environmental protection expenditure on research and development (R&D). For this purpose we employ a selection model which allows first examining which factors are the determinants of whether any such expenditure occurs and in a second step we explain how much is spent on each type of expenditure given that it occurs.

Most of the earlier empirical literature has focused on efficiency and effectiveness of environmental policies. The later focus has been on effects of environmental regulations on environmental investment, innovation and technological change. For instance, the relationship between environmental policy stringency and innovation efforts has been demonstrated empirically by Lanjouw and Mody (1996), Jaffe and Palmer (1997), Brunnermeiera and Cohen (2003), Horbach (2008) and Carrion-Flores and Innes (2010) where increases in pollution abatement control expenditures (assumed to be correlated to policy stringency) lead to jumps in environmental patent counts and/or R&D expenditure. Horbach (2008) also finds that environmentally innovative firms in the past are also more likely to innovate in the present. Lee and Alm (2004) look at the impact of uncertainties surrounding the enactment and the enforcement of environmental legislation on firm's investment in air pollution abatement equipment.

Also, there is growing evidence that firms respond to other external pressures for voluntary overcompliance such as local/interest group pressures, customer demand or other social pressures (see e.g. Heal (2008)). In addition to that, the standard industrial organisation literature has stressed the importance of firm characteristics, such as firm size, firm ownership, foreign competition, technological characteristics, capital intensity and others, when explaining investment in general. For example, the attention to firm-specific factors when explaining environmental expenditure has been given by Collins and Harris (2002, 2005) and Haller and Murphy (2012).

Our paper contributes to the sparse empirical literature on interactions between environmental regulation and corporate behaviour. Unlike previous studies, we exploit a comprehensive survey of environmental expenditure and investment for a quite long time period. Our empirical results show that firms that use carbon intensive fuels such as oil and gas are more likely to spend to and invest in the environment. Larger, more profitable and more energy intensive firms are more likely to incur environmental expenditure/investment. Overall, an important finding of our econometric analysis is that environmental regulation both on the national and international levels are highly relevant motivations for environmental expenditure and investment.

The remainder of the paper is organised as follows. We present our theoretical framework and define the variables to be used in our empirical analysis in Section 2. In Section 3 we outline the data sources. Our empirical findings are discussed in Section 4. The final section highlights the contributions of this paper and concludes.

2. Empirical strategy

The empirical problem of our study is to find the determinants of firm environmental expenditure and investment. A number of econometric issues need to be tackled. First, we might have sample selection bias since our dependent variable (the environmental expenditure/investment level) can be measured only if the individual firm decides to do expenditure/investment. The Heckman selection model (1979) can be used to deal with this problem. Second, the Heckman sample selection model is more commonly used in studies with cross-section data and less with panel data. Wooldridge (1995) proposed a similar to Heckman selection model to deal with selection bias using the nature of longitudinal data. The traditional Heckman two-stage selection model does not account for individual firm heterogeneity effects what might be an important issue in environmental expenditure decisions. These decisions might be based on unobservables such as firm culture, firm social responsibility, management background etc. Thus, we adopt the Wooldridge (1995) empirical estimation strategy to account not only for selection bias but also for firm time-invariant individual effects.

2.1 A selection model of the environmental investment/expenditure decision

The first stage of this analysis constructs a model of the probability of environmental expenditure/investment focusing on the role of environmental policy variables in this decision. The underlying expenditure/investment decision is modelled as

$$Y_{it}^* = \mathbf{z}_i\boldsymbol{\beta} + \mathbf{x}_{it}\boldsymbol{\gamma} + \boldsymbol{\eta}_i + \boldsymbol{\varepsilon}_{it},$$

where Y_{it}^* is a latent variable that underlines an observed indicator variable that captures whether or not a firm spends according to the following rule:

$$Y_{it} = \begin{cases} 1 & Y_{it}^* > 0 \\ 0 & \text{otherwise,} \end{cases}$$

and

$$\Pr(Y_{it} = 1 | \mathbf{z}_i, \mathbf{x}_{it}, \boldsymbol{\eta}_i) = \Phi(\mathbf{z}_i\boldsymbol{\beta} + \mathbf{x}_{it}\boldsymbol{\gamma} + \boldsymbol{\eta}_i + \boldsymbol{\varepsilon}_{it}),$$

where \mathbf{z}_i are firm specific time invariant variables; \mathbf{x}_{it} are firm specific time variant variables; $\boldsymbol{\eta}_i$ are firm specific time invariant unobservables such as firm culture, firm social responsibility, management background etc. The first stage uses the cross-sectional probit regressions to predict whether or not the individual firm do environmental expenditure/investment in a given period. As the determinants of the investment/expenditure decision a number of variables are included in the probit models.

We also need the variables which are likely to satisfy the necessary exclusion restrictions, i.e. they are likely to affect the probability of firm investing in the environment, but are unlikely to affect changes in a firm's investment levels except through their effect on investment decision.

For the instruments we use the dummy variables indicating whether individual firms use carbon intensive fuels such as gas or oil. These instruments satisfy the exogeneity/exclusion condition as it is unlikely that the particular fuel type usage affects the level of environmental investment/expenditure given that we control for other energy/fuel use by individual firms.

2.2 A regression model identifying environmental investment/expenditure determinants

In the second stage we estimate the fixed effect model:

$$Y_{it} = \mathbf{x}_{it}\boldsymbol{\omega} + \boldsymbol{\eta}_i + \boldsymbol{\rho}_{1999} * \boldsymbol{\lambda}_{1999} + \dots + \boldsymbol{\rho}_{08} * \boldsymbol{\lambda}_{08} + \boldsymbol{\varepsilon}_{it},$$

where $\boldsymbol{\lambda}_{1999}, \dots, \boldsymbol{\lambda}_{08}$ are the inverse Mills ratios estimated in the first selection stage using the probit model for each year. The coefficients of the inverse Mills ratios ($\boldsymbol{\rho}_t$) might suggest that

the factors, that predict which firms make decision whether to invest (or make expenditure) into environmental measures or not, are correlated with the factors determining how much firms do invest or make expenditures related with the environment protection. The significance of the inverse Mills ratios indicates that accounting for sample selection is important.

2.3 Variables included as potential determinants of firm environmental investment/expenditure

Based on the earlier empirical and theoretical literature and the available data, we consider firm economic situation, capital stock, energy intensity and firm-specific energy prices as explanatory variables. We also control for technological characteristics by using six NACE industry dummies. Additionally, we control for the introduction of the EU Emission Trading System (EU ETS). The descriptive statistics of all variables are presented in Table 1. In turn, we provide a brief motivation for including the above explanatory variables in our models.

In principle, firm's economic performance is an important determinant of investment as the rate of investment might be constrained by the supply of funds (e.g. see a comprehensive survey by Jorgenson (1971)). We measure firm's economic performance as a ratio of firm value added and employee number. We expect the coefficient of this explanatory variable to be positive.

Firm size in which firms operate might also affect investment activity. We might think that large and monopolistic firms may have fewer incentives to invest and to innovate, whereas small firms in competitive markets are forced to be better than their competitors by reducing their production costs and developing new products. On the other hand, larger firms are more likely to be more polluting and there may be economies of scale in environmental expenditure and investment (Haller and Murphy 2012). We use firm's lagged capital stock (machinery and buildings) to account for firm size effects on environmental investment/expenditure.

We expect firms that are more energy intensive spend more on pollution reduction due to their higher pollution levels and associated pollution abatement costs. We measure energy intensity as a ratio of energy used in MWh and employee number. Also, we control for energy prices by constructing a firm-specific Tornqvist energy price index. We expect that higher energy prices should increase the probability of making an investment.

As mentioned in the introduction, Swedish firms are subject to national and international environmental regulations. In Sweden there are three different types of excise duties, which are levied on fuels – energy tax, CO₂ tax and SO₂ tax. Petrol, diesel, oil, kerosene, natural gas and coal are directly subject to energy tax, CO₂ tax and SO₂ tax. The general principle is that excise duties are only to be paid if the fuel is used as motor fuel or for heating purposes. Apart from these directly excisable fuels, excise duties are also levied on certain other fuels when sold or used as motor fuels or for heating purposes. This applies to all mineral oils, fats from both vegetable and animal sources and fatty acid methyl esters. Taxable is also any product used as motor fuel and any hydrocarbon, which is sold or used for heating purposes. However, aviation spirit and jet fuel are not subject to excise duty when used for air

navigation. Petrol has been taxed since 1924 and diesel since 1937. Energy tax on oil and coal used for heating purposes and electricity has been collected since the nineteen fifties. The carbon dioxide and sulphur taxes were introduced in 1991. The CO₂ tax base rate is presently 1,05 SEK (about 0,11 euro) per kilo CO₂ emitted. However, due to exemptions and special rules the actual rate paid by industry is considerably lower (0,15-0,20 SEK) The SO₂ tax is levied on the sulphur content in the fuel and is based on a tax rate of 30 SEK (3,08 euro) per kilo.

That these policies are successful have been document by several studies. For instance, Brännlund and Lundgren (2010), Lundgren and Marklund (2010) and Brännlund et al. (2011) study the impact of a CO₂ tax on firm level profits and environmental performance during 1990-2004. They find that environmental performance, in terms of carbon intensity in production, is positively correlated with the CO₂ tax, while the impact on profitability is ambiguous.

In addition to the national policies, since 2005 large polluters of CO₂ emissions have been covered under the European Union's Emission Trading System. Firms subject to these regulations have strong incentives to reduce their emissions by contracting their output or by employing and/or installing less polluting production technologies.

To explore the effects of environmental policies introduced by Swedish authorities, we use total energy-environmental taxes paid by firms. Unfortunately, these data are available only for a very small set of firms and, thus, this variable is excluded from the main models of this study. For the EU ETS, we use a dummy variable which identifies whether a firm belongs to the EU ETS. Also, to control for the dynamics of CO₂ price, we use an average annual price of CO₂ as well as its variance for the years 2005-2008. Finally, we control for the introduction of the EU ETS by using a dummy variable for the 2005-2008 period corresponding for the first years of the EU ETS. The interaction term between the ETS-firm dummy and the time dummy representing the first four years of the EU ETS will show whether the post-2005 period for ETS firms was associated with higher environmental expenditure and investment:

$$Y_{it} = \theta_1 (Y05_i * ETS_i) + x_{it}\delta + \eta_i + \rho_{1999} * \lambda_{1999} + \dots + \rho_{08} * \lambda_{08} + \varepsilon_{it},$$

where θ_1 is a coefficient of the interaction term. It will indicate the effect of the EU ETS on environmental investment/expenditure.

3. Data

Our dataset consists of several independent datasets collected and owned by Statistics Sweden (SCB). The environmental expenditure variables come from "Environmental protection expenditure in industry" survey. It has been in place since 1999 but it has become compulsory since 2001. The statistics cover total investments in environmental protection and current expenditure. The expenditure is broken down between types of costs, environmental domains (air, water, waste, biodiversity and landscape, protection of soil and groundwater and other),

30 economic activities for industries, and five size classes of numbers of employees (20-49, 50-249, 250-499, 500-999, more than 1000). The sample frame consists of enterprises with 20 employees or more¹ whose main activity is in Mining and quarrying (NACE 10-14), Manufacturing (NACE 15-36) and Electricity, gas and water supply (NACE 40-41). The total sample for each year consists of approximately 1 000 firms. The analysis here focuses on the Mining and quarrying and Manufacturing sectors. Survey forms, reports on methods and quality as well as aggregates obtained from the data are available at www.scb.se.

The other necessary economic, environmental and energy variables for this study were obtained from the other datasets owned by the SCB. Matching of firms across data sets was performed using unique firm-level identifiers.² Our dataset consists of more than seven thousand observations over the period 1999-2008, about 750 per year.³

As only a fraction of firms reports positive values for environmental expenditure and investment, we might have sample selection bias since our dependent variables are censored, i.e. they can be measured only if an individual firm decides to spend or invest in pollution abatement. We will use the Heckman selection models described above to deal with this problem.

4. Results

4.1 Descriptive statistics

Table 1 presents the descriptive statistics of all variables used in this study. Separately, the summary statistics are reported for firms that reported positive environmental expenditure and investment. During the period of our analysis, 86% of firms reported positive environmental expenditure and the share of firms that reported environmental investment was much smaller – 44%. On average, firms spent SEK 3 505.6 thousand and invested SEK 4 950.2 thousand. It is evident that firms that reported positive environmental investment are on average more profitable and capital intensive than firms that reported positive environmental expenditure. Firms that report environmental investments are also more energy intensive than other firms.

The sectoral allocation reveals (see Table 2) that firms in the mining and quarrying sector report larger environmental expenditure and investment. Firms in the wood, pulp and paper; and chemicals, mineral products and plastic sectors invest more in environmental protection than firms in the other sectors.

¹ In 2005, due to the administrative burden on enterprises, Statistics Sweden decided to raise the cut off to enterprises with 50 employees or more instead of the usual 20 employees. To make comparisons with earlier years possible, estimations were made for the size group 20-49 employees.

² To the best of our knowledge, this merge of different datasets has not been done before.

³ Some variables are available for the shorter period.

Table 1 Descriptive statistics

Variables	Measurement units	All observations			If envexp > 0			If envinv >0		
		Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Total investment	SEK, thousands	7 560	2 156.2	12 367.1	5346	2 454.8	11 800.4	3293	4 950.2	18 367.1
Air investment	SEK, thousands	7 560	912.3	6 969.9	5346	1 006.6	6 082.8	3293	2 094.6	10 443.6
Other investment	SEK, thousands	7 560	1 243.9	8 118.0	5346	1 448.1	8 750.0	3293	2 855.7	12 112.7
Total expenditure	SEK, thousands	6 224	3 011.1	8 804.4	5346	3 505.6	9 408.4	2653	5 787.0	12 541.1
R&D expenditure	SEK, thousands	6 224	112.6	867.0	5346	131.0	934.2	2653	213.6	1210.0
Profitability ratio	SEK per employee	7 530	651 602.9	1 215 244.0	5332	680 463.5	1 377 628.0	3287	743 799.6	1 761 912.0
Capital	SEK, thousands	7 559	262 775.1	979 509.6	5345	297 683.9	1 059 913.0	3293	489 293.0	1 394 015.0
Energy intensity	MWh per employee	6 944	219.0	614.1	5064	244.0	677.1	3193	343.4	813.5
Tornqvist energy price index	Base year 2000	6 953	1.302	0.395	5071	1.360	0.383	3195	1.216	0.379
ETS firms	dummy variable, 1 if ETS firm	7 560	0.100	0.300	5346	0.114	0.318	3293	0.183	0.387
Mining and quarrying	dummy variable, 1 if NACE 10-15	7 560	0.017	0.130	5346	0.017	0.129	3293	0.024	0.152
Food, beverages, textiles and clothing	dummy variable, 1 if NACE 15-19	7 560	0.118	0.323	5346	0.117	0.322	3293	0.114	0.318
Wood, pulp and paper	dummy variable, 1 if NACE 20-22, 36	7 560	0.226	0.418	5346	0.217	0.412	3293	0.217	0.412
Chemicals, mineral products and plastic	dummy variable, 1 if NACE 23-26	7 560	0.155	0.362	5346	0.169	0.375	3293	0.185	0.388
Metal, metal products	dummy variable, 1 if NACE 27-28	7 560	0.136	0.343	5346	0.137	0.344	3293	0.150	0.357
Machinery and equipment, electronics	dummy variable, 1 if NACE 29-35	7 560	0.347	0.476	5346	0.342	0.474	3293	0.311	0.463
Total energy and environmental taxes	SEK, thousands	1 151	6 321.6	12 766.6	908	6 301.7	12 009.2	850	7 496.7	14 178.6

Table 2 Sectoral allocation of environmental expenditure and investment

Industry	If envexp > 0			If envinv > 0		
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Mining and quarrying	91	12 303.6	27 583.0	78	19 566.2	46 138.7
Food, beverages, textiles and clothing	627	3 742.4	6 901.4	375	2 722.4	6 492.5
Wood, pulp and paper	1 160	4 489.4	11 277.5	715	10 074.1	27 727.1
Chemicals, mineral products and plastic	906	4 579.2	9 233.0	608	5 487.7	12 099.0
Metal, metal products	733	3 575.9	10 298.2	494	3 492.9	21 459.8
Machinery and equipment, electronics	1 829	1 802.7	5 637.6	1023	1 455.5	3 838.1

The dynamics of environmental expenditure and investment is presented in Figure 1. It is evident that average environmental expenditure increased significantly after the year 2004. It is an important question, whether this increase can be explained by the introduction of the EU ETS in 2005. Oppositely, average environmental investment has slightly declined since 2005.

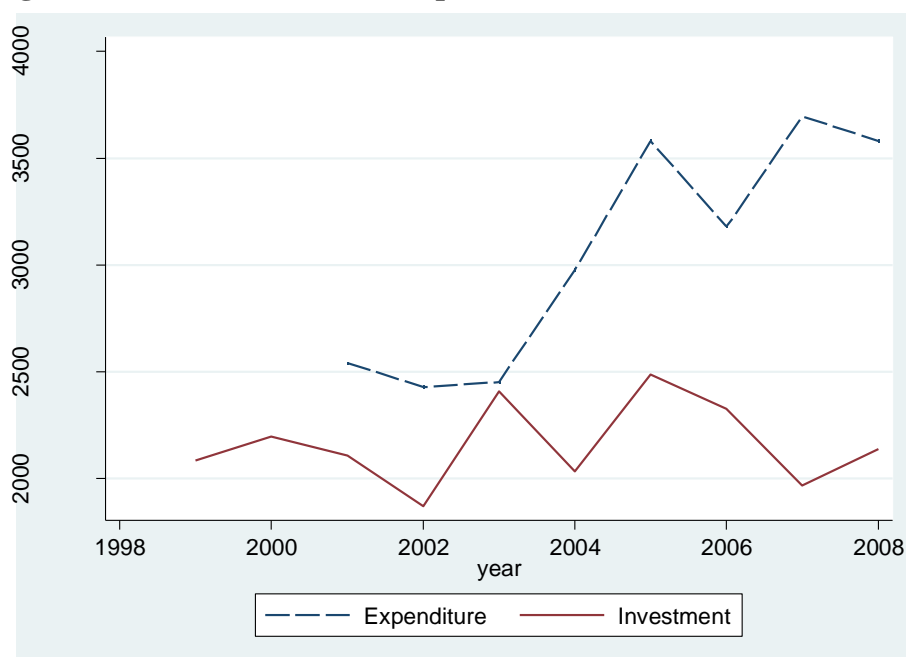
Figure 1 Mean environmental expenditure and investment, 1999-2008

Table 3 reports the descriptive statistics for ETS and non-ETS firms. It is evident that ETS firms are larger than other firms in the sample. They are more energy and capital intensive as well as more profitable. On average, ETS firms spend more on environment and invest more in pollution control.

Table 3 Descriptive statistics for ETS and non-ETS firms.

Variables	Measurement units	Non-ETS firms		ETS firms	
		Mean	Obs.	Mean	Obs.
Total investment	SEK, thousands	690.3	6 805	15 369.4	755
Air investment	SEK, thousands	305.4	6 805	6 383.0	755
Other investment	SEK, thousands	384.9	6 805	8 986.3	755
Total expenditure	SEK, thousands	1 355.2	5 584	17 458.3	640
R&D expenditure	SEK, thousands	62.2	5 584	552.3	640
Profitability ratio	SEK per employee	615 492.2	6 775	975 643.2	755
Capital	SEK, thousands	105 345.8	6 804	1 681 515.0	755
Energy intensity	MWh per employee	116.4	6 196	1 068.8	748
Energy price index	Base year 2000	1.332	6 205	1.051	748
Mining and quarrying	dummy variable, 1 if NACE 10-15	0.015	6 805	0.037	755
Food, beverages, textiles and clothing	dummy variable, 1 if NACE 15-19	0.124	6 805	0.066	755
Wood, pulp and paper	dummy variable, 1 if NACE 20-22, 36	0.202	6 805	0.444	755
Chemicals, mineral products and plastic	dummy variable, 1 if NACE 23-26	0.145	6 805	0.249	755
Metal, metal products	dummy variable, 1 if NACE 27-28	0.137	6 805	0.122	755
Machinery and equipment, electronics	dummy variable, 1 if NACE 29-35	0.376	6 805	0.082	755
Total energy and environmental taxes	SEK, thousands	1 812.6	537	10 265.1	614

4.2 First stage regression results

The estimates of the first stage Heckman selection model are presented in Table 4. We report only the pooled probit models due to space constraints.⁴ The selection model for environmental investment in the third column indicates that – other things equal – larger firms (in terms of capital) and firms that use carbon intensive fuels as oil and gas are more likely to invest. The likelihood that firms do environmental expenditure is determined by a different set of factors: more profitable, more energy intensive firms as well as firms that use carbon intensive fuels have higher probability of incurring environmental expenditure (see column 1).

Table 4 First stage pooled Heckman selection models (probit models)

Variables	Expenditure		Investment		
	TOTAL (1)	R&D (2)	TOTAL (3)	AIR (4)	OTHER (5)
ETS firms	0.116 (0.0959)	0.682*** (0.0795)	0.321*** (0.0803)	0.355*** (0.0759)	0.405*** (0.0770)
Profitability (lag)	2.00e-07*** (6.01e-08)	-7.68e-09 (1.63e-08)	-1.06e-08 (1.63e-08)	-2.08e-08 (1.58e-08)	-1.65e-08 (1.64e-08)
Energy intensity (lag)	0.000230*** (6.36e-05)	8.28e-05* (4.24e-05)	6.41e-05 (4.45e-05)	0.000134*** (4.20e-05)	8.64e-05** (4.31e-05)
Capital (lag)	1.03e-08 (2.37e-08)	1.11e-07*** (1.94e-08)	2.21e-07*** (3.62e-08)	1.36e-07*** (2.28e-08)	1.62e-07*** (2.75e-08)
CO ₂ price	0.0161*** (0.00404)	0.00411 (0.00383)	-1.39e-05 (0.00326)	0.00322 (0.00348)	-0.000832 (0.00328)
Variance of CO ₂ price	-0.0176 (0.0120)	-0.00128 (0.0113)	-0.0172* (0.00967)	-0.0113 (0.0105)	-0.0189* (0.00978)
Tornqvist price index (lag)	0.781*** (0.0753)	0.176** (0.0751)	-0.532*** (0.0641)	-0.502*** (0.0708)	-0.463*** (0.0642)
NACE1 (mining)	-0.178 (0.179)	0.239 (0.172)	0.325* (0.169)	0.190 (0.169)	0.378** (0.166)
NACE2 (food, clothes)	-0.0784 (0.0715)	-0.225*** (0.0794)	-0.101 (0.0634)	-0.187*** (0.0694)	-0.0812 (0.0636)
NACE3 (wood, paper, furniture)	-0.0879 (0.0588)	-0.148** (0.0662)	-0.162*** (0.0535)	-0.156*** (0.0589)	-0.170*** (0.0541)
NACE4 (chemicals, minerals)	0.0805 (0.0685)	-0.179** (0.0708)	0.0753 (0.0583)	0.152** (0.0613)	0.00493 (0.0584)
NACE5 (metals)	-0.0599 (0.0686)	-0.272*** (0.0777)	0.0894 (0.0612)	0.00992 (0.0653)	0.0439 (0.0612)
Oil dummy (lag)	0.168*** (0.0354)	0.144*** (0.0367)	0.199*** (0.0310)	0.172*** (0.0325)	0.188*** (0.0308)
Gas dummy (lag)	0.169*** (0.0423)	0.275*** (0.0409)	0.373*** (0.0363)	0.452*** (0.0367)	0.298*** (0.0357)
Constant	-0.469*** (0.102)	-1.563*** (0.103)	0.263*** (0.0850)	-0.382*** (0.0931)	0.0673 (0.0852)
No. of observations	4,965	4,965	4,965	4,965	4,965

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

We are also interested in whether the EU ETS has affected firms' environmental investment and expenditure. We find that EU ETS firms are more likely in making environmental

⁴ The first stage probit models used for the second stage fixed effects models must be run separately for each year. Then, the inverse Mills ratios are constructed and inputted in the second stage. Thus, each fixed effect model has at least eight corresponding probit models. These results can be provided by the authors upon request.

investment and R&D expenditure decisions (see columns 2-5 in Table 4). The resultant price of CO₂ in the EU ETS market had a positive and significant effect only on the probability of total environmental expenditure (see column 1 in Table 4), but not investment.

4.3 Second stage regression results

Table 5 and Table 6 show the results of the Heckman selection models without and with accounting for fixed effects, respectively. The coefficients of the inverse Mills ratios are statistically significant showing that the two firms' decisions on whether to spend and how much to spend are significantly correlated. This indicates that we should use selection models to investigate our empirical research questions.

Table 5 Second stage pooled Heckman selection models

Variables	Expenditure		Investment		
	TOTAL (1)	R&D (2)	TOTAL (3)	AIR (4)	OTHER (5)
ETS firms	3,718*** (1,145)	299.4 (421.3)	7,210*** (1,526)	2,766** (1,351)	5,216*** (1,218)
ETS*Y05	3,924*** (1,186)	416.6 (309.6)	-4,295** (1,758)	1,682 (1,556)	-5,601*** (1,326)
Y05	598.6 (755.0)	-275.0 (298.9)	856.5 (1,604)	1,184 (1,590)	158.0 (1,242)
Profitability (lag)	-0.000278 (0.000199)	0.000957*** (0.000172)	0.00349*** (0.000860)	0.00109 (0.000762)	0.00296*** (0.000660)
Energy intensity (lag)	0.855 (0.531)	-0.120 (0.127)	4.388*** (0.702)	2.516*** (0.591)	1.733*** (0.535)
Capital (lag)	0.00392*** (0.000206)	1.57e-05 (4.76e-05)	0.00136*** (0.000268)	3.31e-05 (0.000229)	0.00115*** (0.000207)
CO ₂ price	-115.0** (48.05)	1.919 (14.77)	23.75 (80.30)	-3.271 (77.68)	19.86 (62.01)
Variance of CO ₂ price	135.5 (116.1)	72.39** (36.25)	116.2 (200.1)	28.56 (190.8)	139.2 (155.7)
Tornqvist price index (lag)	-5,150*** (1,183)	86.44 (313.5)	-1,675 (1,528)	-2,511* (1,496)	-433.8 (1,169)
NACE1 (mining)	6,215*** (1,899)	780.6* (453.9)	9,343*** (2,600)	2,612 (2,418)	7,718*** (1,934)
NACE2 (food, clothes)	1,581** (765.2)	-437.2 (270.4)	-115.1 (1,229)	-157.6 (1,254)	377.9 (944.3)
NACE3 (wood, paper, furniture)	-406.7 (655.2)	-461.3* (239.6)	2,610** (1,105)	1,232 (1,091)	2,584*** (864.0)
NACE4 (chemicals, minerals)	1.613 (719.5)	90.01 (243.6)	-836.9 (1,112)	-875.7 (1,073)	-320.2 (862.2)
NACE5 (metals)	1,235* (739.5)	-113.3 (268.3)	-670.9 (1,162)	299.2 (1,134)	-641.5 (891.4)
Lambda	-15,290*** (3,126)	170.2 (465.6)	-4,440** (2,148)	-1,492 (1,640)	-3,137* (1,838)
Constant	13,066*** (2,529)	-419.6 (956.0)	3,428 (2,138)	4,541* (2,371)	1,449 (1,840)
No. of obs. (uncensored)	3,992	787	2,367	1,422	2,059

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

One of the most interesting research questions is whether the introduction of the EU ETS in 2005 has had any effect on firms' environmental behaviour. To explore this question we use the interaction term between the dummy representing the EU ETS time period (2005-2008) and the dummy variable indicating whether the individual firm was covered by this scheme. Since it was not a voluntary scheme, we can consider the EU ETS as an exogenous factor which can allow us to identify the causal policy effect.

The fixed effects and pooled Heckman selection models produce very similar estimates. The results from Table 5 and Table 6 indicate that the EU ETS policy had different effects on environmental expenditure and investment: the effect on environmental expenditure is positive (column 1), while it is negative on other than air pollution related investment (column 5). We might think that the EU ETS encouraged ETS firms to redistribute their environmental expenses, i.e. to postpone or decrease environmental investment in other than air related areas and to increase environmental expenditure in order to comply with the EU ETS regulations. For instance, Jaraitė et al. (2010) have found that internal (staff) and capital costs accounted for most of the expenditure associated with the introduction of the EU ETS in Ireland.

We also included the EU ETS allowance price and its volatility to extend our analysis on EU ETS effects. We find no evidence that EU ETS price or its volatility had a significant impact on the environmental investment or expenditure levels perhaps indicating that this price was too low to trigger any changes in firms' expenditure and investment decisions.

Table 6. Fixed effects Heckman selection models

VARIABLES	Expenditure		Investment		
	TOTAL (1)	R&D (2)	TOTAL (3)	AIR (4)	OTHER (5)
ETS*Y05	3,809*** (418.2)	237.5 (398.0)	-3,154 (2,043)	2,656 (2,132)	-5,435*** (1,565)
Y05	4.231 (296.2)	-219.1 (386.2)	344.9 (1,956)	2,005 (2,359)	-222.9 (1,571)
Profitability (lag)	0.00123*** (0.000371)	0.000854 (0.000726)	0.00392* (0.00231)	-0.000332 (0.00400)	0.00737*** (0.00179)
Energy intensity (lag)	1.183 (1.440)	1.052 (1.158)	-9.507** (4.043)	-17.94** (8.167)	-5.709 (3.751)
Capital (lag)	0.000477 (0.000390)	-0.000296 (0.000671)	-0.00697*** (0.00124)	-0.00485*** (0.00137)	-0.00142 (0.000891)
CO ₂ price	-10.75 (14.27)	6.560 (16.86)	64.34 (90.16)	-6.847 (104.8)	53.43 (71.97)
Variance of CO ₂ price	25.31 (34.99)	56.74 (41.38)	-79.50 (217.3)	-51.00 (243.2)	30.59 (175.1)
Tornqvist price index (lag)	1,246* (660.7)	420.2 (1,556)	5,197 (3,722)	5,568 (3,881)	1,784 (2,144)
Inverse Mills ratios	y	y	y	y	y
Constant	1,875** (899.3)	-4,041 (4,902)	12,710*** (3,969)	16,610*** (5,016)	10,633*** (3,958)
No. of obs. (uncensored)	3,992	787	2,367	1,422	2,059
R-squared (within)	0.055	0.087	0.029	0.056	0.026
Number of firms	1,060	281	766	535	704

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The fixed effect models produce the opposite than expected signs for capital and other potential environmental investment/expenditure determinants' coefficients. Baltagi and Pinnoi (1995) explain that this may happen as fixed effects estimate the short-run effects and pooled OLS models produce the expected sign, suggesting the long-run impact. Thus, it is important to consider both estimation methods.

Our capital variable, i.e. buildings and machinery, is used as a proxy for the firm size. As expected, we find that firm size is an important factor explaining the amount of environmental expenditure and investment (see Table 5). However in the fixed effect models we get a negative and significant relationship between investment and capital size (see Table 6). As mentioned above, this might be explained by the fact that fixed effect models reflect more short-run relationships.

A similar argument can be also applied for other variables such as firm energy intensity. In the long-run, firm energy intensity is a significant and positive factor determining environmental investment which is consistent with the economic logic. However in the short-run, the increased energy intensity potentially means changes in production processes, increases in conventional capital investment and additional expenses that could encourage firms to postpone their environmental expenditure and investment.

We also find that firm economic performance is an important factor determining the amount of firm's environmental investment and expenditure. As expected the availability of the funds allows firms to invest in environmental projects.

As Swedish firms are also subject to the strict national environmental regulations, they have strong incentives to reduce their emissions by contracting their output or by employing less polluting production technologies. To explore how national environmental policies have affected firm environmental expenditure and investment, we use total energy-environmental taxes paid by firms. The results in Table 7 show that taxes had a significant and positive effect on firm environmental and R&D expenditure, but the effects on environmental investment are not clear and needs further research using more extensive datasets.

5. Conclusions

This paper investigates the determinants of environmental expenditure and investment. The two-stage Heckman selection models are estimated using a panel dataset of Swedish industrial firms tracked from 1999 to 2008. We find that firms that use carbon intensive fuels such as oil and gas are more likely to spend to and invest in the environment. More profitable and more energy intensive firms are more likely to incur environmental expenditure. Additionally, ETS firms are expected to spend on environmental R&D. Once the decision to commit resources has been taken, ETS firms during the first four years of the EU ETS have higher environmental expenditure. As regards environmental investment we find that larger firms, and ETS firms are more likely to invest. ETS firms are also probable to invest on reducing air pollution problems. The effect of the EU ETS is negative on the level of other than air pollution related investment, which is opposite to the effect on environmental expenditure. A reasonable explanation is that the EU ETS encouraged firms to restructure their

environmental expenses by postponing environmental investment in other than air related areas and increasing environmental expenditure in order to comply with the EU ETS regulation. The role of CO₂ price was irrelevant in all models.

Table 7 Heckman selection models with taxes

Variables	Expenditure		Investment		
	TOTAL	R&D	TOTAL	AIR	OTHER
	(1)	(2)	(3)	(4)	(5)
Total taxes (lag)	0.219** (0.107)	0.101*** (0.0136)	0.0279 (0.110)	-0.0185 (0.0773)	-0.0530 (0.0865)
ETS firms	2,177 (3,488)	275.2 (708.8)	2,245 (4,388)	1,383 (3,241)	2,235 (3,225)
ETS*Y05	4,956 (4,150)	862.6 (598.1)	-2,570 (4,943)	2,835 (4,295)	-4,494 (3,561)
Y05	-1,631 (4,762)	-1,303** (664.0)	-2,180 (6,096)	129.4 (5,375)	-2,320 (4,342)
Profitability (lag)	-0.00141 (0.00234)	0.000850*** (0.000270)	0.00396 (0.00299)	0.000894 (0.00204)	0.00340 (0.00224)
Energy intensity (lag)	-0.563 (1.512)	-0.165 (0.158)	1.320 (1.740)	1.560 (1.256)	-0.681 (1.363)
Capital (lag)	0.00379*** (0.000562)	-2.87e-05 (7.25e-05)	0.00101 (0.000779)	-0.000101 (0.000520)	0.000975 (0.000615)
CO ₂ price	-303.0 (260.4)	4.716 (25.72)	71.00 (278.0)	46.19 (214.6)	-10.36 (205.1)
Variance of CO ₂ price	512.1 (615.5)	126.3* (64.55)	595.7 (730.3)	174.3 (534.5)	667.5 (584.1)
Tornqvist price index (lag)	-10,757 (7,219)	680.6 (670.5)	-5,413 (6,134)	-7,273 (4,450)	-1,790 (4,488)
NACE1 (mining)	13,124* (6,840)	-125.0 (717.3)	21,068*** (7,509)	5,162 (5,790)	17,626*** (5,481)
NACE2 (food, clothes)	2,965 (4,891)	-1,153* (612.7)	2,044 (5,682)	-37.33 (4,336)	2,375 (4,262)
NACE3 (wood, paper, furniture)	-1,227 (4,465)	-440.1 (539.6)	13,847** (5,403)	3,426 (4,145)	11,363*** (3,893)
NACE4 (chemicals, minerals)	1,762 (4,335)	-216.6 (597.4)	1,712 (4,991)	-1,358 (3,893)	2,331 (3,711)
NACE5 (metals)	5,128 (4,731)	-349.0 (607.5)	1,843 (5,848)	2,655 (4,203)	2,937 (4,047)
Lambda	-32,966** (16,802)	1,061 (1,041)	-26,625 (16,675)	-3,014 (7,379)	-20,893 (13,757)
Constant	25,572* (14,805)	-2,086 (2,061)	15,668 (11,265)	11,354 (8,941)	10,719 (10,087)
No. of observations (uncensored)	794	595	691	514	637

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Firm economic performance is another important factor determining the amount of environmental investment and expenditure. This corroborates the idea that environmental investment and expenditure to some extent are motivated by strategic reasons and as a consequence integrated with a good economic performance (Heal 2008).

The analysis of the small sub-sample of our dataset reveals that environmental-energy taxes seem to motivate the level of environmental and R&D expenditure, but the effect on investment is not clear and needs further research.

Overall, an important finding of our econometric analysis is that environmental regulation both on the national and international levels are highly relevant motivations for environmental expenditure and investment. Whether these policies have been sufficient to drive environmental innovation has to be investigated by future research.

References

- Baltagi, B. H. and Pinnoi, N. (1995). Public capital stock and state productivity growth: Further evidence from an error components model *Empirical Economics* 20: 351-359.
- Brunnermeiera, S. B. and Cohen, M. A. (2003). Determinants of environmental innovation in US manufacturing industries. *Journal of Environmental Economics and Management* 45: 278-293.
- Brännlund, R. and Lundgren, T. (2010). Environmental Policy and Profitability – Evidence from Swedish Industry. *Environmental Economics and Policy Studies* 12: 59-78.
- Brännlund, R., Lundgren, T. and Marklund, P.-O. (2011). Environmental performance and climate policy. Working paper No. 06, Centre for Environmental and Resource Economics. Umeå.
- Carrion-Flores, C. and Innes, R. (2010). Environmental innovation and environmental performance. *Journal of Environmental Economics and Management* 59: 27-42.
- Collins, A. and Harris, R. I. D. (2002). Does plant ownership affect the level of pollution abatement expenditure? *Land Economics* 78: 171-189.
- Collins, A. and Harris, R. I. D. (2005). The impact of foreign ownership and efficiency on pollution abatement expenditure by chemical plants: Some UK evidence. *Scottish Journal of Political Economy* 52: 747-768.
- Haller, S. A. and Murphy, L. (2012). Corporate Expenditure on Environmental Protection. *Environmental and Resource Economics* 51: 277-296.
- Heal, G. (2008). *When Principles Pay: Corporate Social Responsibility and the Bottom Line*. New York: Columbia Business School Publishing.
- Heckman, J. J. (1979). Sample selection bias as a specification error. *Econometrica* 47: 153-161.
- Horbach, J. (2008). Determinants of environmental innovation - New evidence from German panel data sources. *Research Policy* 37: 163-173.
- Jaffe, A. B. and Palmer, K. (1997). Environmental Regulation and Innovation: A Panel Data Study. *The Review of Economics and Statistics* 79: 610-619.
- Jaraitė, J., Convery, F. and Di Maria, C. (2010). Assessing the transaction costs of firms in the EU ETS: lessons from Ireland. *Climate Policy* 10: 190-215.
- Jorgenson, D. W. (1971). Econometric studies of investment behaviour: a survey. *Journal of Economic Literature* 9: 1111-1147.
- Lanjouw, J. O. and Mody, A. (1996). Innovation and the international diffusion of environmentally responsive technology. *Research Policy* 25: 549-571.
- Lee, A. I. and Alm, J. (2004). The Clean Air Act Amendments and Firm Investment in Pollution Abatement Equipment. *Land Economics* 80: 433-447.
- Lundgren, T. and Marklund, P.-O. (2010). Climate Policy and Profit Efficiency. CERE Working paper No. 11, Centre for Environmental and Resource Economics. Umeå.
- Wooldridge, J. M. (1995). Selection Corrections for Panel Data Models Under Conditional Mean Independence Assumptions *Journal of Econometrics*. *Journal of Econometrics* 68: 115-132.