Climate Change, Investment and Carbon Markets and Prices – Evidence from Manager Interviews

Carbon Pricing for Low-Carbon Investment Project

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Executive Summary

The EU ETS was designed to deliver a carbon price for Europe to help achieve Europe's 2020 targets greenhouse gas emission targets. As such, an essential component of the policy framework is to support low-carbon investment. Are low-carbon investment choices prioritized within manufacturing firms in an environment of many competing interests and pressures? Is the market's carbon price integrated into strategic decision-making processes? Does it enhance the profitability of low-carbon investment for the industry?

Based on interviews with almost 800 manufacturing firms in six European countries, this study seeks to answer these questions by exploring the impact of EU ETS on climate change related measures on the one hand and clean innovation on the other.

First looking at investment into existing low-carbon measures, we find that a large proportion of firms are pursuing some measures to reduce GHG emissions. For a majority of these (more than 60%) this includes energy- and GHG emissions-saving measures related to their machinery and core processes.
Firms require on average a payback time of four years for investment in energy-saving measures. However, this figure varies widely between firms. Firms at the 90th percentile allow for more generous payback time of seven years, whereas firms at the 10th percentile require 1.5 years. Payback time varies systematically between sectors and countries. Firms in the UK report the lowest average payback times, with a mean of 3.5 years, whereas firms in Poland allow for more than five years, on average.

Second, we consider how industrial firms are integrating the carbon price in their strategies, considering in particular the rationality with which they operate on the market. We find that about 30% of firms that are part of the European Union Emissions Trading System (EU ETS) only participate passively in the market; i.e. they do not consider carbon allowances as a financial asset providing opportunities. Rather, they see the cap implicit in their allowance allotment as something they merely need to comply with. While there are significant differences in EU ETS engagement between sectors, any differences between countries are not significant.

Also, we find that the majority of the 446 EU ETS participants interviewed do not trade on the EU ETS allowance market. Some of these firms do not need to, because their emissions do not exceed the amount of allowances they were allocated. We find support for the concern that those firms do not make their excess allowances available on the market. On average, firms start to sell only if they have an excess supply of 5,000 to 10,000 allowances. The total number of excess allowances held by firms below this ``trading threshold" is rather small, under 10% of all excess allowances, however.

Firms expect carbon prices to be considerably higher in the future, compared with current levels in the EU ETS. We find an average expected carbon price of €40 for the post-2012 trading period. Compared to the current trading period (Phase II, from 2008 to 2012), firms expect the imposition of tighter caps for Phase III, starting in 2013. The proportion of firms reporting that their allowance allocation does not imply a binding emissions limit falls from 40% in Phase II to less than 10% in Phase III.

Finally, we analyse more specifically low-carbon investment in R&D. Most (70%) firms are engaged in some formal or informal R&D, with the aim of curbing emissions and/or energy consumption ("clean process innovation"). A smaller proportion (40%) is also pursuing "clean product innovation"; i.e. R&D with the aim of developing products that can help customers to reduce their emissions. There are significant differences between countries when it comes to clean innovation. According to the study, most active on product innovation is Germany, on process innovation is France with lowest levels of innovative activities observed in Hungary and Poland.

We also use regression analysis to consider the effect of climate policy on innovation at the firms in our sample. We provide two pieces of evidence in support of a causal link between company-specific caps – i.e. the amount of allowances companies receive for free in the EU ETS – and "clean" R&D by firms.
As a first piece of evidence we find a significant positive association between the expectations firms hold about the future stringency of their cap and "clean" innovation. This relationship is robust to including a broad range of control variables.
Furthermore, we find that firms within the EU ETS which are just below the thresholds established for free allowances are engaging more strongly in climate change related product innovation than firms that are just above the threshold (and thus will continue to receive free allowances). There is a discontinuity in both expected stringency as well as "clean" innovation at the thresholds that are implied by the latest set of criteria that the European Commission has proposed for allocating free emissions allowances after 2012.[1] This result suggests that the ongoing practice within the EU ETS, of generously allocating allowances for free to manufacturing sectors leads to less innovation than would otherwise be the case.

[1] The Commission takes this decision for each sector based on whether it is sufficiently (i) carbon intensive, (ii) trade intensive or (iii) both.

1 Introduction

In advanced economies, the industrial sector is directly responsible for about a third of greenhouse gas (GHG) emissions (IEA, 2009). Understanding the drivers and barriers that affect company behavior related to climate change is therefore essential to design effective policies for reducing emissions, to prevent dangerous levels of global warming. At the same time, private-sector firms are also the key players when it comes to investments in research and development (R&D); "clean" innovation is critical for achieving the transition to a low-carbon economy. The relationship between "clean" R&D investments and climate change policy becomes all the more relevant if the fruits of these investments spill over across international borders and help to reduce emissions in countries with few or no climate change policies. Currently, some view this possibility as the main justification for European climate change policy, given that EU emissions reductions alone would not be sufficient to prevent dangerous global climate change from occurring.

To date, the empirical evidence on what firms are doing (or not) to curb GHG emissions is rather limited and has been collected through either mail surveys or case studies (McKinsey & Ecofys, 2005, Kenber *et al.*, 2009). This paper examines the link between climate change regulation and investment and innovation, using detailed survey data for a representative sample of firms. The data were collected by interviewing managers on climate-change and energy related issues using a novel method that circumvents various types of bias that plague more traditional survey formats. We applied this approach to a sample of approximately 800 manufacturing firms in six European countries from August to October 2009.

Based on this dataset, we obtain a number of new descriptive results regarding the behavior of businesses related to climate change. In particular, we find that:

- A large proportion of firms are pursuing some measures to reduce GHG emissions. For a majority of these (more than 60%) this includes energy- and GHG emissions-saving measures related to their machinery and core processes (see Leib et al., 2010).
- Most (70%) firms are engaged in some formal or informal R&D, with the aim of curbing emissions and/or energy consumption ("clean process innovation"). A smaller proportion (40%) is also pursuing "clean product innovation"; i.e. R&D with the aim of developing products that can help customers to reduce their emissions. There are significant differences between countries when it comes to clean innovation. According to the study, most active on product innovation is Germany, on process innovation is France with lowest levels of innovative activities observed in Hungary and Poland. (see Martin et al., 2010a).
- We find that firms require on average a payback time of four years for investment in energy-saving measures. However, this figure varies widely between firms. Firms at the 90th percentile allow for more generous payback time of seven years, whereas firms at the 10th percentile require 1.5 years. Payback time varies systematically between sectors and countries. Firms in the UK report the lowest average payback times, with a mean of 3.5 years, whereas firms in Poland allow for more than five years, on average.
- We find that about 30% of firms that are part of the European Union Emissions Trading System (EU ETS) only participate passively in the market; i.e. they do not consider carbon allowances as a financial asset which provides opportunities. Rather, they see the cap implicit in their allowance allotment as something they merely need to comply with. While there are significant differences in EU ETS engagement between sectors, any differences between countries are not significant (see Martin et al., 2010b).
- We find that the majority of the 446 EU ETS participants interviewed does not trade on the EU ETS allowance market. Some of these firms do not need to buy because their emissions do not exceed the amount of allowances they were allocated. However, we also find support for the concern that those firms do not make their excess allowances available on the market. On average, firms start to sell only if they have an excess supply of 5,000 to 10,000 allowances. The

total number of excess allowances held by firms below this ``trading threshold" is rather small, under 10% of all excess allowances (see Anderson et al., 2010).

- Firms expect carbon prices to be considerably higher in the future, compared with current levels in the EU ETS. We find an average expected carbon price of €40 for the post-2012 trading period.
- Compared to the current trading period (Phase II, from 2008 to 2012), firms expect the imposition of tighter caps for Phase III, starting in 2013. The proportion of firms reporting that their allowance allocation does not imply a binding emissions limit falls from 40% in Phase II to less than 10% in Phase III.

Apart from descriptive statistics, we use regression analysis to analyze the effect of climate policy on innovation at the firms in our sample. We provide two pieces of evidence in support of a causal link between company-specific caps – i.e. the amount of allowances companies receive for free in the EU ETS – and "clean" R&D by firms.

First, we find a significant positive association between the expectations firms hold about the future stringency of their cap and "clean" innovation. This relationship is robust to including a broad range of control variables. (see Martin *et al.*, 2010a).

Second, we find that firms within the EU ETS which are just below the thresholds established for free allowances are engaging more strongly in climate change related product innovation than firms that are just above the threshold (and thus will continue to receive free allowances). There is a discontinuity in both expected stringency as well as "clean" innovation at the thresholds that are implied by the latest set of criteria that the European Commission has proposed for allocating free emissions allowances after 2012.[2] This result suggests that the ongoing practice within the EU ETS, of generously allocating allowances for free to manufacturing sectors leads to less innovation than would otherwise be the case (see Martin *et al.*, 2010b).

The remainder of this paper is organized as follows: Section 2 describes the process of interviewing managers about various aspects of company behavior related to climate change. Section 3 reviews and provides summary statistics of our behavioral measures related to investment, as well as regarding future expectations. Section 4 examines the link between innovation, future expectations and climate policy. Section 5 concludes.

2 Interviewing managers

2.1 Interview Methodology

Our survey builds upon and substantially extends previous work on climate change policies and management practices by Martin *et al.* (2009). We conduct structured telephone interviews with managers at randomly selected manufacturing facilities in Belgium, France, Germany, Hungary, Poland and the UK. The interview setup follows the management survey design pioneered by Bloom and Van Reenen (2007), in that the interviewer engages interviewees in a dialogue with open questions that are meant not to be answered by "yes" or "no". On the basis of this dialogue, the interviewer then assesses and ranks the company along various dimensions. Note that our setup adopts a double-blind strategy: interviewees do not know that the interviewers are scoring their answers and interviewers do not know performance characteristics of the firm they are interviewing. This interview format is designed to avoid several sources of bias common in conventional surveys (Bertrand and Mullainathan, 2001). For instance, experimental evidence shows that a respondent's answers can be manipulated by making simple changes to the ordering of questions, to the way

[2] The Commission takes this decision for each sector based on whether it is sufficiently (i) carbon intensive, (ii) trade intensive or (iii) both.

questions are framed, or to the scale on which respondents are supposed to answer. By asking open-ended questions and by delegating the task of scoring the answers to the interviewer, we seek to minimize cognitive bias of this type. Possible cognitive bias on the part of the interviewers can be controlled for using interviewer-fixed effects in the regression analyses. Another common observation with survey data is that respondents are tempted to report attitudes or patterns of behavior that are socially desirable but may not reflect what they actually think and do. This problem may be exacerbated in situations where respondents do not have a definite attitude toward the issues they are asked about but are reluctant to admit that. Our research design addresses this issue in two ways. First, the interviewer starts by asking an open question about an issue and then follows up with more specific questions, or asks for some examples in order to evaluate the respondent's answer as precisely as possible. Second, the results of the interviews are then linked to independent data on economic performance, as a validation exercise.

2.2 Interview Practice

Using the ORBIS database maintained by Bureau Van Dijk we obtained contact details for 644,000 manufacturing firms in Belgium, France, Germany, Hungary, Poland and the UK[3]. We randomly selected companies from that list to solicit an interview. To ensure sufficient coverage of firms subject to the EU ETS (hereafter, EU ETS firms), we also sampled manufacturing firms at random from the Community Independent Transaction Log (CITL) in these countries.

Interviewers made "cold calls" to production facilities (not head offices), gave their name and affiliation with the London School of Economics and then asked to be put through to the environmental manager. In the case of EU ETS firms, interviewers asked for the person responsible for the EU ETS, as it is listed in the CITL. Table 1 reports the number of calls made and various statistics about the response rates.

Table 1: Response rate and numbers in each country

	# of Interviews	# of Firms Interviewed	# of ETS Firms Interviewed	# of Non ETS Firms Interviewed	Total Firms Contacted	Refused	Response Rate
Belgium	139	136	97	39	185	49	0.74
France	141	141	91	50	240	99	0.59
Germany	139	139	96	43	362	223	0.38
Hungary	75	75	43	32	96	21	0.78
Poland	81	81	58	23	143	62	0.57
UK	212	207	61	146	513	306	0.40
Total	787	779	446	333	1539	760	0.51

Note: There are more interviews than interviewed firms, as we conducted several interviews with different partners in a small number of firms.

An ordinal scale of 1 to 5 was adopted to measure various management practices related to climate change. For each aspect of management ranked in this way, interviewers were instructed to ask a number of open questions. Questions were ordered such that the interviewer started with a fairly open question about a topic and then probed for more details in subsequent questions, if necessary. The goal was to benchmark the practices of firms according to a few common criteria. For instance, rather than asking the manager for a subjective assessment of the management's awareness of climate-change issues, we gauged this by how formal and far-reaching the discussion of climate-change topics is in current management. To verify the consistency of the interviewer's scoring, a subset of randomly selected interviews was double-scored by a second team member who listened in.

[3] For more details on the survey, see Martin *et al.*, 2010a and Martin *et al.*, 2010b.

The interviews seeks to gather information on both the effectiveness and the competitiveness effects of climate change policies, particularly of the EU ETS, in a random sample of European manufacturing firms. The questionnaire (see appendix) is divided in four sections. The first section examines the current and anticipated future effects of the EU ETS. The second section deals with prices for energy and CO_2, competition and other external drivers of climate-change related management practices. The third section inquires about specific measures that were adopted by firms and others which were considered but eventually discarded. The last section gathers information on relevant company characteristics.

3 Descriptive evidence from interviewing managers

3.1 Carbon-reducing measures

Managers were first asked to tell the interviewer about all carbon-reducing measures implemented at their business site. Interviewers recorded all measures mentioned by the manager on a long list of potential measures which are grouped into six top-level categories (Figure 1): heating and cooling energy generation, machinery, energy management, other production measures and non-production measures.[4] In Figure 2, we report the proportion of firms that reported conducting at least one measure in the various categories.

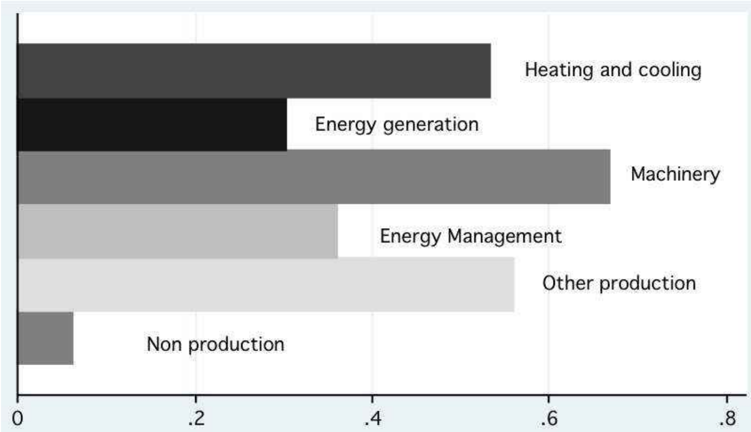
Figure 1: Carbon reducing measures captured by the management interviews

I. Heating and cooling:	☐ Optimized use of process heat ☐ Modernization of cooling/refrigeration system ☐ Optimization of air conditioning system ☐ Optimization of exhaust air system and/or district heating system
II. More climate-friendly energy generation on site :	☐ Installation of combined heat and power (CHP) plant / cogeneration ☐ Biogas feed-in in local combined heat and power plant or domestic gas grid ☐ Switching to natural gas ☐ Exploitation of renewable energy source
III. Machinery :	☐ Modernization of compressed air system ☐ Other industry-specific production process optimization / machine upgrade ☐ Production process innovation
IV. Energy management :	☐ Introduction of energy management system ☐ Upgrade of an existing energy management system ☐ (External) Energy audit ☐ Installation of timers attached to machinery ☐ Installation of (de-)centralized heating systems
V. Other measures on production site :	☐ Modernization of lighting system ☐ Energy-efficient site extension/improved insulation/introduction of building management ☐ Employee awareness campaigns and staff trainings ☐ Non-technical reorganization of production process ☐ Installation of energy-efficient IT-system ☐ Improved waste
VI. Beyond production on site :	☐ Introduction of climate-friendly commuting scheme ☐ Consideration of climate-related aspects in investment and purchase decisions ☐ Consideration of climate-related aspects in distribution ☐ Customer education program ☐ Participation in carbon offsetting schemes

Note: This corresponds to question 22 of the interview (see Appendix)

[4] Managers were not prompted with all these options. Interviewers also recorded in plain text measures that were not in the list.

Figure 2: Implementation of carbon saving measures



Notes: The figure shows a histogram of the types of carbon saving measures reported by interviewed firms.

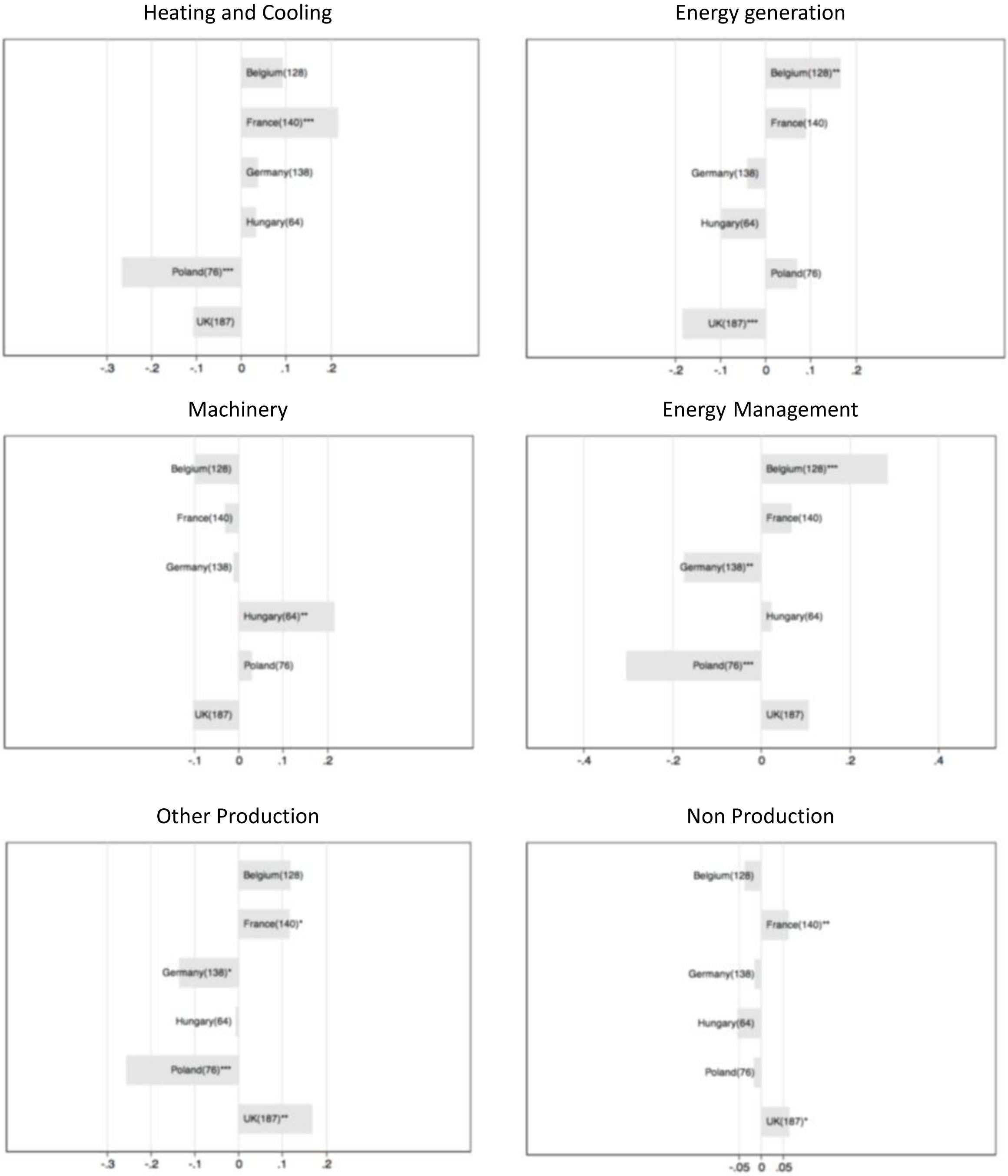
A large proportion of firms are pursuing some measure to reduce GHG emissions. For the largest proportion of firms (more than 60%), this includes energy- and GHG-saving measures related to their machinery and core processes. A comparison across countries reveals significant differences (Figure 3), but the ranking of countries varies greatly with the type of measure. For example, Belgium seems to be leading in energy generation measures, whereas implementation of measures to reduce emissions from heating and cooling is most widespread among French firms.

3.2 Clean Innovation

Firms can implement existing measures to reduce their GHG emissions, as described in the previous section. Another path for future abatement is to innovate: the company can either invest in finding cleaner production processes or develop new and cleaner products, thereby reducing their customers' future emissions. Figure 4 shows the distribution of the scores for clean process and product innovation[5]. An example of clean process innovation could be the development of a less energy-consuming way to transform limestone into quicklime. Clean product innovation would for example be the invention of a new tyre with which cars consume less petrol. We see that almost 70% of firms are engaged in some form of clean process innovation; only 40% engage in clean product innovation. Figure 5 shows that clean product innovation is most likely to occur in firms that are also conducting clean process innovation.

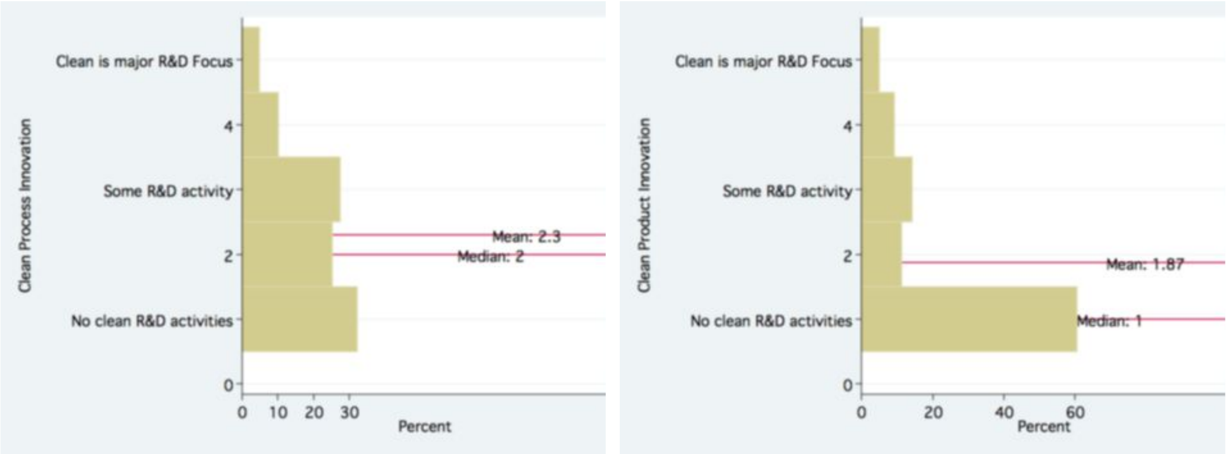
[5] The clean process and product innovation measures are throughout this study taken from the survey responses and we hereafter use interchangeably the term innovation and R&D.

Figure 3: Carbon saving measures across countries



Notes: Each graph shows the average difference – conditional on 3-digit sector controls and noise controls – between firms from different countries in terms of the percentage implementing the respective measures. Stars indicate if these deviations are statistically significant, and at what significance level: ***=1%, **=5%, *=10%.

Figure 4: Distribution of the Clean Innovation Scores

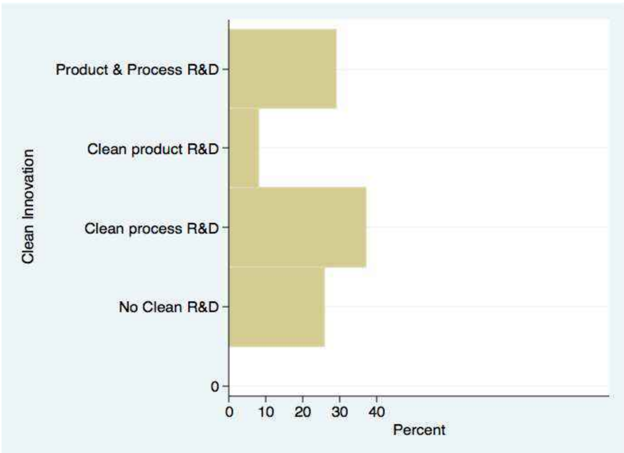


Notes: The figures show a histogram of the scores for each of the two types of clean innovation reported by interviewed firms.

Table 2: Sectors according to their focus on clean innovation

		Clean Product Innovation	
		below average	*above average*
Clean Process Innovation	*below average*	• Cement; • Ceramics; • Fabricated Metals • Food&Tobacco • Publishing • Textile Leather	• Fuels • Machinery&Optics; • Other Basic Metals; • Vehicles
	above average	• Chemicals&Plastic; • Iron & Steel; • Wood & Paper	• Glass • Other Minerals • TV&Communication

Figure 5: The relative frequency of clean process and product innovation



Notes: The figure shows a histogram of the types of clean innovation reported by interviewed firms.

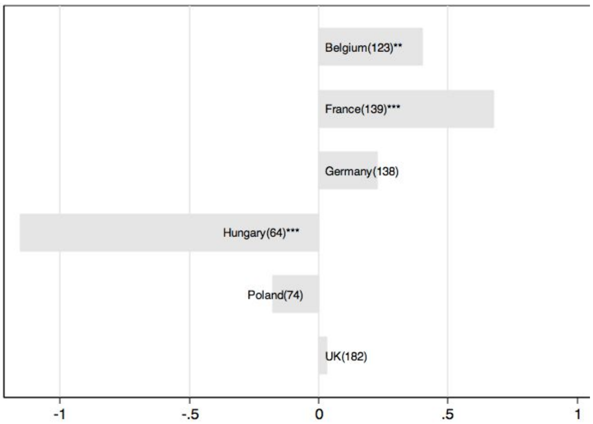
Figure 6 examines whether there are differences in clean innovation between countries in our sample. There is clearly a gap between Western and Central/Eastern European countries, with Poland and Hungary lagging behind, both in terms of process and of product R&D. France emerges as the leader in process, Germany in product R&D. The second panel of Figure 6 explores whether these differences are driven by differences in the specialization of the various economies across sectors.

The figures report average differences between countries while controlling for the 3-digit sector[6]. This makes the differences found in the first panel even more pronounced, suggesting that they are not driven by differences in industrial composition.

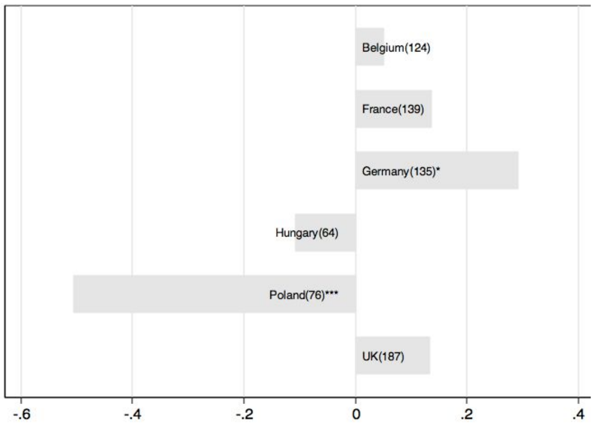
Figure 6: Differences in clean innovative activities between countries

No Industry controls

Process Innovation

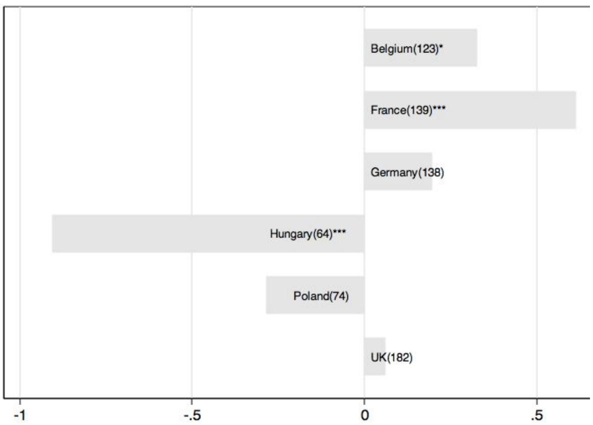


Product Innovation

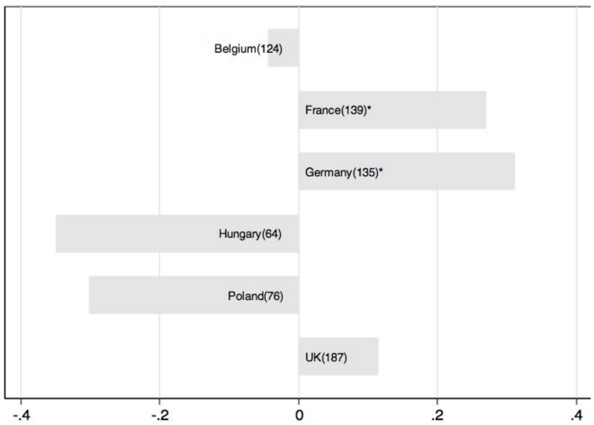


3-digit industry controls

Process Innovation



Product Innovation

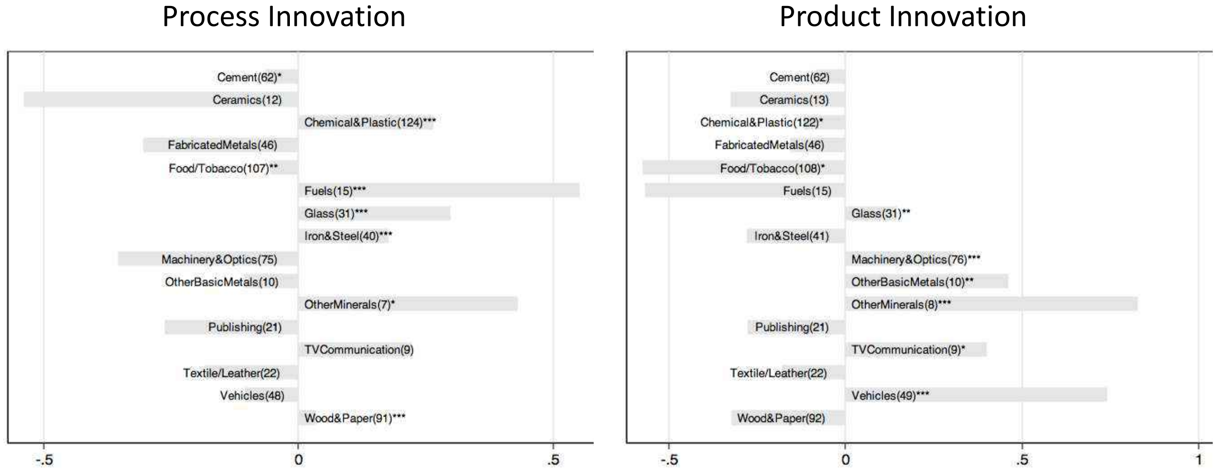


Notes: Each graph shows the average difference - conditional on noise controls - between firms from different countries in terms of the interview scores for process and product innovation described in Figure 4. Stars indicate if these deviations are statistically significant and at what significance level: ***=1%, **=5%, *=10%.

Figure 7 reveals sizeable differences in clean innovation across sectors and between types of innovation. In Table 2, we use this information to group sectors according to their focus on clean technologies. Only three sectors – Glass, Other Minerals and TV & Communication – have above-average scores in both product and process innovation.

[6] We use the NACE rev. 1.1 classification of the ORBIS data.

Figure 7: Differences in clean innovative activities between industries



Notes: Each graph shows the average difference - conditional on noise controls - between firms from different sectors in terms of the interview scores for process and product innovation described in Figure 4. Stars indicate if these deviations are statistically significant and at what significance level: ***=1%, **=5%, *=10%.

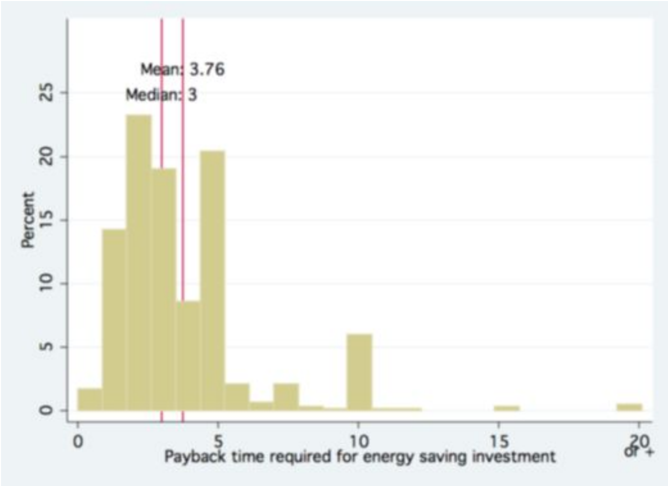
3.3 Decision rules for investment projects to improve energy efficiency

The interviews also touched upon the criteria applied by firms when deciding on investments for improving energy efficiency. Specifically, we asked what payback times are required for such investments, and whether these payback times were longer or shorter than those required for non-energy related investments to cut costs. This relates closely to the literature on the energy-efficiency paradox (See, for example, Jaffe and Stavins, 1994, DeCanio, 1998 or Auffhammer, Sanstad and Hanemann, 2006, for a recent survey); i.e. the observation that firms do not seem to adopt many measures that would provide both a cost reduction and a reduction in emissions, or that the internal rates of return applied to discount the payoffs seem excessively high. In our sample, we find an average payback time of almost four years (Figure 8). However, this figure varies widely between firms. Firms at the 90th percentile allow a more generous payback time of seven years, whereas firms at the 10th percentile require payback within only 1.5 years.[7] Payback time varies systematically between sectors and countries (Figure 9). Firms in the UK report the lowest average payback times, with a mean of 3.5 years, whereas firms in Poland allow for more than five years, on average.

In Figure 10, we examine the interview score indicating whether investment criteria are more or less stringent for energy- and carbon-saving investments compared to others. We see that most firms apply similar criteria. However, about 30% of firms apply either more or less stringent criteria.

[7] To put this into perspective, recall that a project with a 4-year payback and constant annual cash flow over a 15-year lifetime has an internal rate of return (IRR) of 24%.

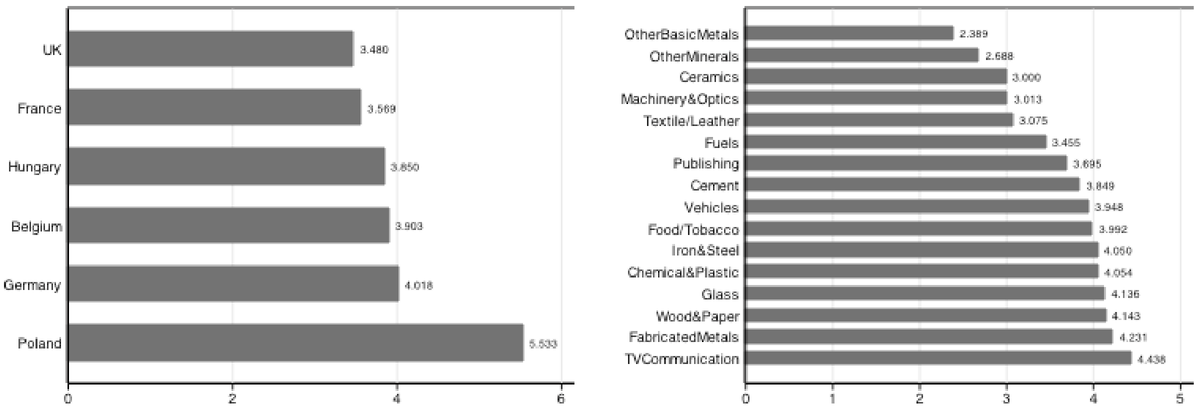
Figure 8: Distribution of payback time required for energy saving investments



Notes: The figure shows a histogram of the payback times (in years) for energy- and carbon-saving investments reported by interviewed firms.

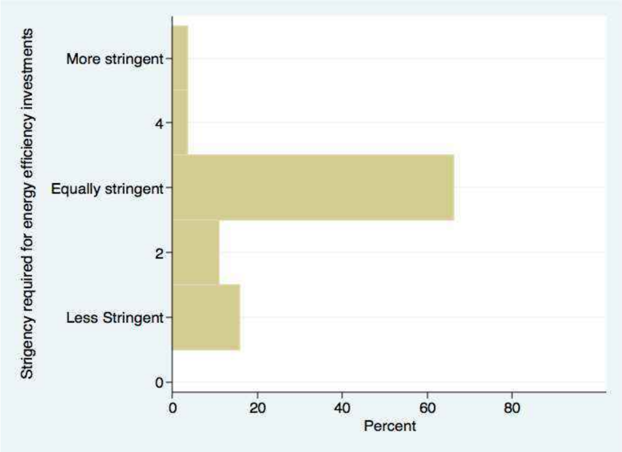
Figure 9: Differences in payback times between countries and industries

Across countries
Across Industries



Notes: Each graph shows the average payback times for energy-efficiency improving investments for firms from different countries or sectors.

Figure 10: Relative stringency of criteria for energy saving investments



Notes: The figure shows a histogram of the interview score measuring whether the firm applies more stringent criteria for investments in energy- and carbon-saving technologies than for other investments.

3.4 Behavior in the EU ETS

In this section, we examine a series of questions in our interviews relating to the behavior of firms within the EU ETS allowance market[8].

Figure 11 examines the interview score capturing the firm's vision of trading opportunities in the EU ETS. We find that about 30% of firms participate only passively in the EU ETS; i.e. they do not consider carbon allowances as a financial asset which provides opportunities. Rather, they see the EU ETS as something they merely need to comply with. While there are significant differences in EU ETS engagement between sectors, any differences between countries are not significant (Figure 12).

Further, Figure 13 shows that the majority of EU ETS participants does not trade on the EU ETS market. Some of these firms do not need to trade because their emissions exactly match their allocated allowances. Others, however, may have excess allowances that they do not supply to the market. Some policymakers are concerned that this behavior exacerbates the shortage of allowances and hence drives up the allowance price.[9] We examine this hypothesis by running probit regressions on the binary event "Selling on the EU ETS market" derived from question 7 of our interview (see Appendix). The key explanatory variable includes a set of dummy variables calculated on the basis of the distribution across firms of excess allowance allocations in 2008, $Excess_{i2008}$, with[10],

$$Excess_{i2008} = ALLO_{i2008} - CO_{2i2008}$$

We split firms with positive excess allowances into five equally sized groups, according to the size of their excess distribution. That is, the five groups are defined by the quintiles of the distribution of excess allowances (1,701, 5,387, 11,722 and 32,100 allowances). Let each group be represented by

[8] See Anderson *et al.*, 2010

[9] Theoretically, there are a number of potential reasons. These include firms wanting to bank permits in order to hedge against future carbon price increases, as well as transaction and information costs related to trading or non-optimizing behavior. For instance, Murphy and Stranlund (2007) suggest that an "endowment effect" – the overvaluation of items in one's possession – could prevent firms from selling permits they were allocated for free. A similar effect will derive from "status quo bias" (Kahneman *et al.,* 1991, Samuelson and Zeckhauser, 1988).

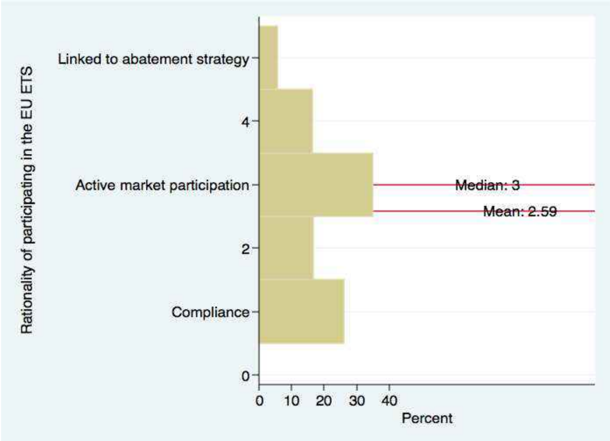
[10] $ALLO_{i2008}$ and $CO_{2\ i2008}$ are respectively the allocation and emissions for firm i in 2008, as given in the CITL.

a dummy variable Q_{qi} where the subscript *q* represents the quintile, so that we can express the latent equation underlying the probit as:

$$\text{Propensity to Sell}_i = \sum_q \beta_q Q_{qi} + \beta_x X_i + \varepsilon_i \qquad (1)$$

where we include a vector of additional control variables, X. Table 3 reports the results. Before running regressions of equation 1, in columns 1 and 2 we start with regressions of the event "Trading on the ETS"; i.e. both, buying or selling. Column 1 shows that trading is weakly correlated with the total amount of CO_2 a firm emits. Column 2 shows that it is more strongly correlated with the rationality score we derived from our interviews, which underlines the internal consistency of this score. In columns 3 to 5, we examine the decision to sell allowances on the EU ETS market. Columns 4 and 5 show that only firms with excess allowance amounts in the 3rd quintile and higher have a heightened probability of selling allowances on the EU ETS market. The table reports marginal effects, so the coefficient estimate implies that a firm with about 5,000 allowances or more to spare has on average a 50% higher probability of selling some or all of those allowances on the EU ETS market. This implies that allowances are more likely not to be traded in the allowance market when the revenue derived by their owners is small, a finding that could be rationalized by a fixed cost of trading. How important is this issue on aggregate? To answer this question, we examine what share of the excess allowances is held by firms in quintiles 1 and 2. Figure 14 illustrates this share in the distribution of excess allowances. On aggregate, this problem seems to be of minor importance, as far less than 10% of excess allowances fall into the "no trade" category.

Figure 11: Rationality of market participation

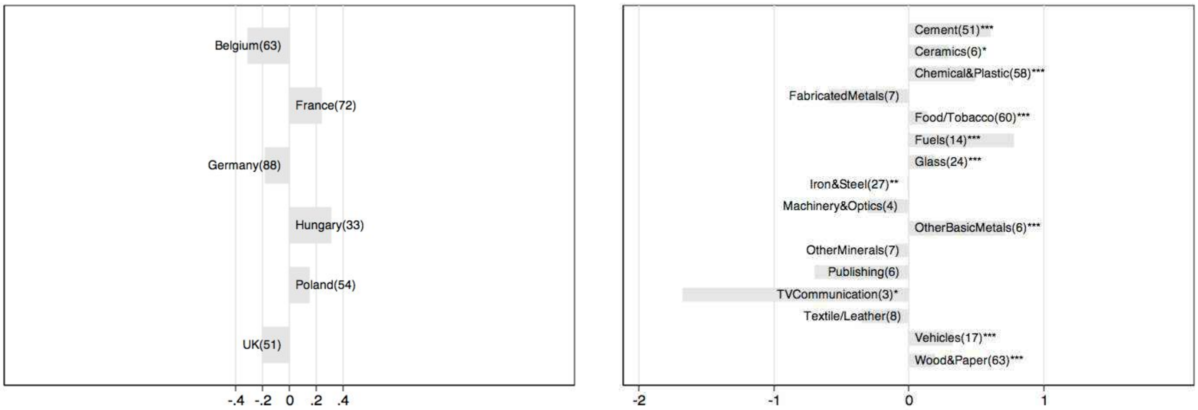


Notes: The figure shows a histogram of the interview score measuring whether the firm is acting rationally on the EU ETS market.

Figure 12: Rationality of market participation across countries and sectors

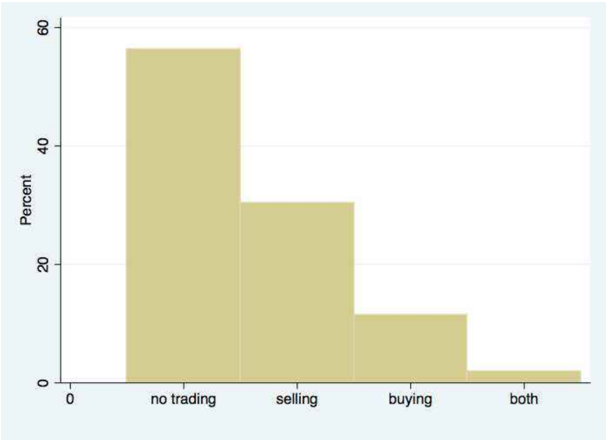
Across countries controlling for 3-digit sectors

Across sectors



Notes: Each graph shows the average difference - conditional on noise controls - between firms from different countries or sectors in terms of the interview score for market rationality described in Figure 11. Stars indicate if these deviations are statistically significant, and at what significance level: ***=1%, **=5%, *=10%.

Figure 13: Buying and selling in the EU ETS



Notes: The figure shows the proportion of firms (of all EU ETS regulated firms in our sample) which trade on the EU ETS market.

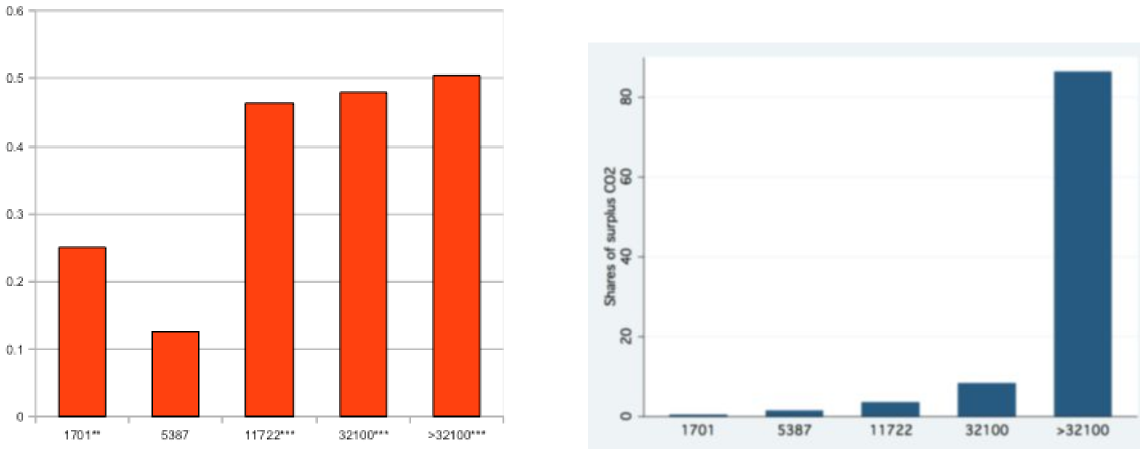
Table 3: Regressions of firms' trading decisions

		(1)	(2)	(3)	(4)	(5)
Dependent Variable		Buys or Sells in ETS			Sells in ETS	
CO_2 consumption		0.043*	0.036	0.022	-0.002	-0.009
	lnCO2	(0.023)	(0.023)	(0.021)	(0.025)	(0.025)
EU ETS Rationality Score			0.074**	0.062**		0.065**
			(0.030)	(0.028)		(0.029)
Overallocation in 2008 [number of permits]	0-1701				0.251**	0.255**
					(0.122)	(0.125)
	1702-5387				0.126	0.121
					(0.129)	(0.131)
	5388-11722				0.465***	0.477***
					(0.101)	(0.102)
	11723-32100				0.479***	0.483***
					(0.100)	(0.100)
	>32100				0.504***	0.504***
					(0.108)	(0.110)
Observations		223	223	223	223	223

Notes: This table presents the results of five probit regressions. The dependent variable is derived from interview responses to question 7. In columns (1) and (2) it takes value 1 if the firm is trading on the EU ETS. In columns (3) to (5), the variable only takes value 1 if the firm is only selling allowances. CO_2 consumption and overallocation in 2008 data are taken from the CITL dataset. Stars indicate statistical significance level: ***=1%, **=5%, *=10%.

Figure 14: Barriers to selling?

Pro a ility o elling istri ution o cess llo ances



Notes: Figure (a) presents the coefficients of the probit regression of column (4) in Table 3, each bar representing the probability that a firm with excess allowances within that range will sell allowances on the EU ETS market. Figure (b) represents the shares of the total amount of excess allowances in each quintile. Stars indicate statistical significance level: ***=1%, **=5%, *=10%.

3.5 What firms expect

Investment decisions depend on the expectations held by investors. In order to elicit this information, the interview included a number of questions on expectations. This section reports on our findings, starting with an examination of differences in these expectations between firms, countries and sectors. Subsequently, we discuss expectations about the future of the EU ETS.

3.5.1 Prices

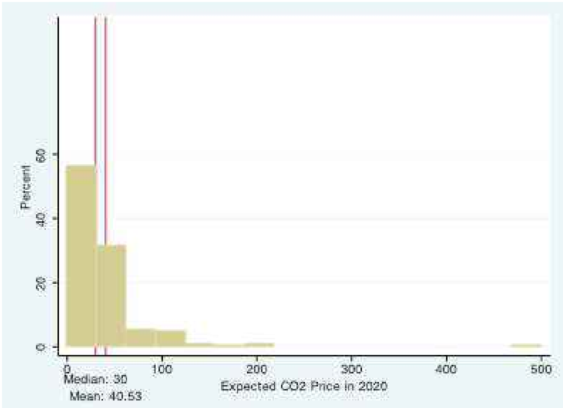
Figure 15 reports the distribution of the expected price of emitting one tonne of carbon dioxide in 2020. Forecasts range between 0 and 500. The median price reported is €30, the mean €40.

There are substantial differences, not only between different firms but also between countries and sectors, as shown in Figure 16. French firms expect a much higher price, of €50 on average, whereas UK firms expect a more modest €28, on average. Across sectors, the highest price is expected by firms in TV and Communication, with an average of €78, the lowest by firms in the Fuels sector, at close to €23.

There is also a sizeable variation across sectors and countries with respect to the mere existence of a price expectation. Figure 17 shows that more than 80% of interviewed Polish managers actually have a carbon price expectation versus less than 5% of the Hungarian managers that we interviewed. At the sector level, the highest proportion of firms with an expectation occurs in the Glass sector (55%), whilst the lowest percentage is only 18%, in Machinery and Optics.

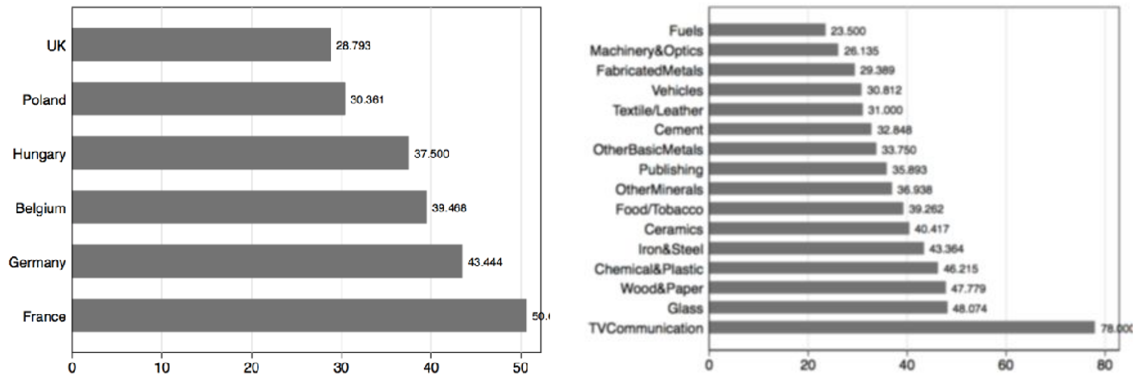
We also asked interviewees about their knowledge of the current price of a tonne of CO_2 on the EU ETS, as a way of gauging their awareness of the market and the potential integration of this price in investment and trading decisions. Again, there is a lot of variation between sectors and countries, as shown in Figure 18, with Poland and the Fuels industry exhibiting the largest shares of managers aware of the carbon price.

Figure 15: Distribution of price expectations across sectors



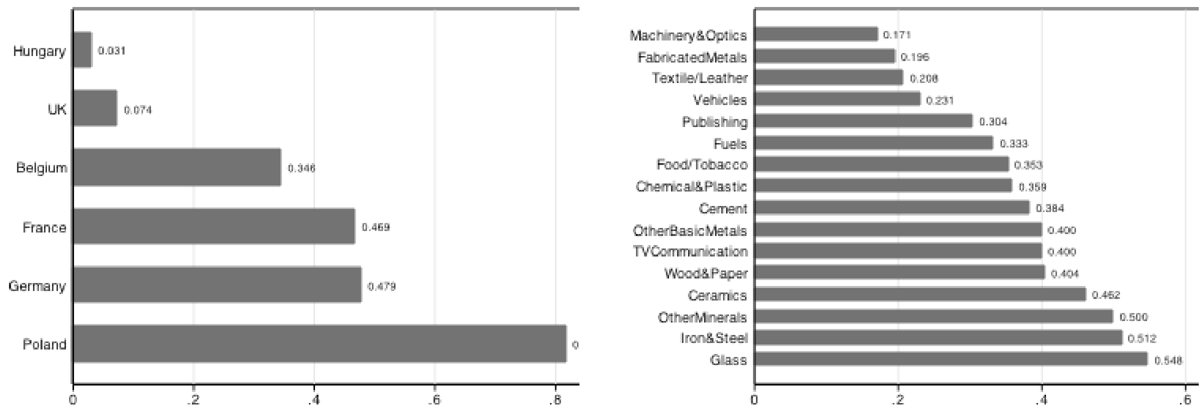
Notes: The figure shows a histogram of the price of a tonne of CO_2 that interviewed firms expect on the EU ETS market.

Figure 16: Price expectations across industries and countries



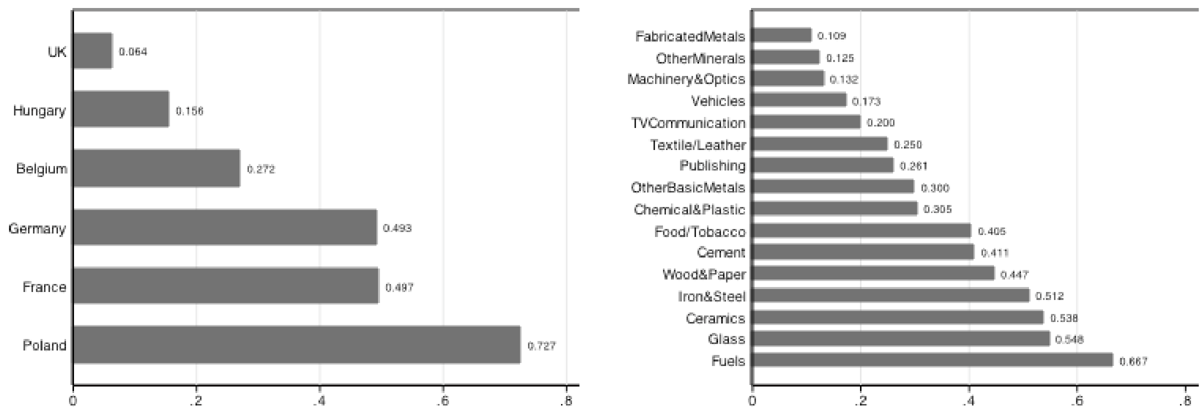
Notes: The figures show average carbon price expectations for 2020 for all interviewed firms that reported price expectations (i.e. both EU ETS and non EU ETS firms).

Figure 17: Existence of Price expectations



Notes: The figures show what proportion of firms in a country or a sector reported a carbon price expectation in our sample.

Figure 18: Knowledge about current prices



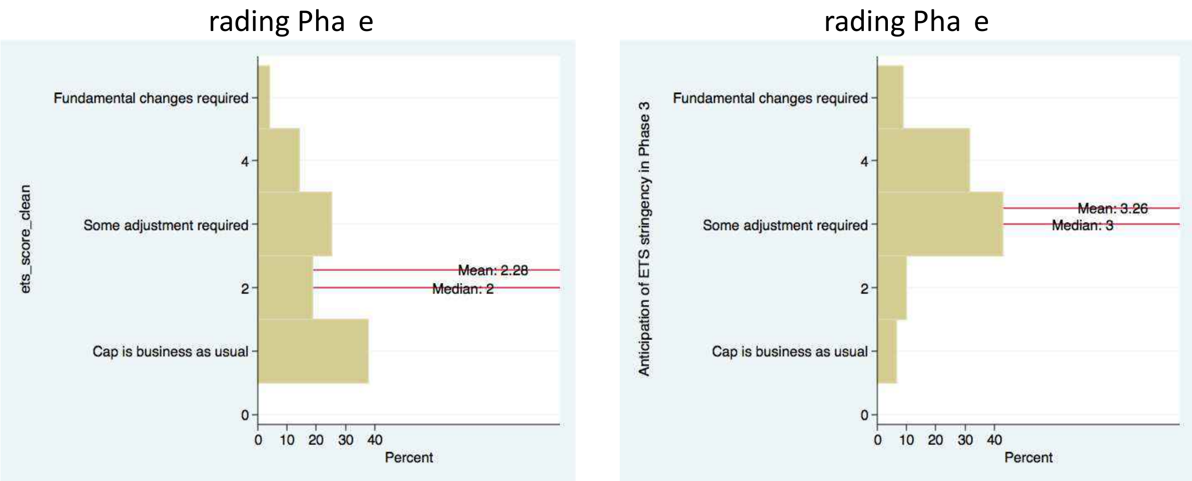
Notes: The figures show what proportion of firms in a country or a sector knew the current carbon price in the EU ETS.

3.5.2 Expected stringency of EU ETS

We also asked firms about their expectations regarding the stringency of the cap on emissions implied by their participation in Phase III of the EU ETS. Put differently, we wanted to know how hard it would be for them to limit their future emissions to the amount they receive in free allowances (or how expensive if they do not reduce their emissions, and need to buy allowances). A firm's response to this question would depend on (i) how costly it would be to reduce its emissions, on (ii) how many allowances it receives for free and on (iii) the price they expect on the market and therefore the expected overall allocation.

We asked a similar question regarding the stringency of the cap imposed by the current Phase II of the trading system. Figure 19 reports on the resulting scores. Firms clearly expect more stringent caps for Phase III. The proportion of firms answering that the cap they receive will allow them to continue under business-as-usual terms declined, from almost 40% to less than 10%. That said, few firms expect, even for Phase III, that fundamental changes would be needed in order to meet their cap.

Figure 19: Expected stringency and current perceived stringency



Notes: The figure for Trading Phase II shows how stringent firm-specific caps are perceived to be. The figure for Trading Phase III shows what stringency firms expect for the Trading Phase starting in 2013.

4 What is driving investment in climate-change related innovation?

Having described in sections 2 and 5 firms' investment in R&D related to climate change and their expectations for the future, this section, examines whether there is a link between the two[11]. Tables 4 reports results from regressions of the process innovation score whereas Table 5 reports the equivalent regressions for product innovation.

In column 1 we start first by regressing the innovation scores on a set of dummy variables indicating whether a firm is part of the EU ETS in either Phase II or III or both. For process innovation this does not lead to a significant coefficient. For product innovation we find a coefficient that is significant at 10%, however only for participation in Phase 2. Hence there is no strong evidence that ETS firms in general differ in their innovativeness from non-ETS firms. In column 2 we add both price expectations and expectations about the future stringency of the firm level cap as explanatory variables. We find positive coefficients for both variables and with both types of innovation. However, we only get significant coefficients for the expected stringency of the cap. Thus it seems that the stringency of

[11] See Martin *et al.*, 2010a

the emissions cap is more relevant for R&D decisions than the price. This is an interesting suggestion, as a simple model of company behavior would tend to predict the opposite: since the EU ETS is a cap-and-trade system the only thing that should matter for firms' allocation and investment decisions is the (expected) emissions price. Company-specific caps should only be relevant for determining the distribution of rents that emerge from imposing scarcity on a formerly free good (GHG pollution). The notion that allocation decisions are independent of the distribution of allowances has been referred to as the "independence property" of emissions trading (Montgomery, 1972, Hahn and Stavins 2010).

An alternative explanation for the correlation between stringency and innovation could be that we are picking up reverse causality or biases due to omitted variables. For example, a firm's perception of stringency is certainly influenced by the availability of cheap technological solutions to reduce emissions. When cheap solutions are not available, a firm is likely to respond that the cap is more stringent. Therefore, such a firm might be more likely to conduct some R&D in response to higher carbon prices. In this case, a positive relationship between R&D and stringency might emerge due to unobserved heterogeneity. We proceed by accounting for this in a number of ways: First, by adding more control variables. Second, by examining what happens when we include current (i.e. Phase II) perceived stringency, rather than future stringency. Third, we use process innovation as a control for un-observed factors in the product innovation regressions. Fourth, rather than using the survey based stringency measures we exploit variations in cap stringency implied by the EU Commission rules for continued free allocation – instead of the requirement to purchase allowances through auctioning. We discuss each approach in turn.

4.1 More control variables

Column 2 in Tables 4 and 5 already includes 3-digit industry dummies. In column 3 we add further controls, such as the size, CO_2 intensity, foreign ownership, etc. of a firm. We note that the stringency coefficient remains positive and significant for product innovation. For process innovation it remains positive but is no longer significant. For completeness we also examine what happens when we drop industry controls in column 4 and when we restrict the sample to only firms that are participating in Phase III. [12] For product innovation, the stringency-innovation relationship is robust in all of these specifications. The results for process innovation are less clear-cut. The stringency coefficient remains insignificant when dropping sector controls but becomes significant when restricting to the ETS sample.

4.2 Using current stringency

Up until Phase II emission allowances have by and large been allocated for free to emitters. Current plans for Phase III stipulate that some firms will have to purchase an increasing fraction of their allowances through an auction or on the open market. Hence, if the relationship between stringency and innovation is driven by variations in the cap rather than abatement cost heterogeneity, we expect that the relationship is weaker or non-existent with current stringency. Again, this turns out to be the case for product innovation where the current stringency coefficient is not significant in columns 6 to 8. For process innovation, the reverse seems to be the case with the current stringency coefficient being positive and significant.

[12] Note that we have the expected stringency score variable only for firms that are regulated by the EU ETS in Phase III. Thus in all columns the stringency effect is identified only from those firms. Including the other firms can be useful, however, to identify the impact of variables on innovation that are relevant for all firms, such as sector, size or noise controls.

Table 4: Regressions of process innovation score

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable.	Process Innovation Score							
Anticipation of ETS Stringency in Phase 3		0.177**	0.107	0.122	0.144**			
		(0.079)	(0.079)	(0.076)	(0.071)			
ETS Stringency in Phase 2						0.093*	0.078*	0.125**
						(0.049)	(0.046)	(0.057)
CO_2 Price expectation by 2020		0.100	-0.041	0.038	0.015			
ln(CO_2 Price)		(0.074)	(0.063)	(0.063)	(0.094)			
CO_2 Intensity in 2008			0.064	0.115***	0.071	0.078	0.139***	0.103**
ln(CO_2/EMP)			(0.048)	(0.038)	(0.051)	(0.049)	(0.037)	(0.046)
Multinational Enterprise			0.140	0.161	0.339	0.172	0.184	0.379*
			(0.148)	(0.132)	(0.228)	(0.144)	(0.130)	(0.228)
R&D Intensive Facility			0.140	0.171*	0.039	0.166	0.197**	0.076
			(0.106)	(0.091)	(0.147)	(0.107)	(0.095)	(0.146)
Employment			0.244***	0.199***	0.162**	0.254***	0.213***	0.187***
ln(emp)			(0.046)	(0.036)	(0.072)	(0.047)	(0.037)	(0.067)
In ETS in Phase 2	-0.237	-0.285	-0.316	-0.129	.	-0.490*	-0.317	.
	(0.198)	(0.198)	(0.241)	(0.235)	.	(0.275)	(0.278)	.
In ETS in Phase 3	0.225	-0.064	0.046	0.061	.	0.322	0.308	.
	(0.304)	(0.340)	(0.350)	(0.345)	.	(0.329)	(0.357)	.
In ETS in Phase 2 and 3	0.388	0.128	-0.053	0.004	.	0.109	0.185	.
	(0.359)	(0.401)	(0.392)	(0.380)	.	(0.381)	(0.378)	.
Observations	732	732	731	731	342	731	731	342
R^2	0.28	0.31	0.40	0.30	0.33	0.38	0.28	0.32
Cluster	153	153	153	153	91	153	153	91
3-digit sector controls	yes	yes	yes	no	no	yes	no	no
Noise Controls	yes	yes	yes	yes	yes	yes	yes	yes

Notes: All columns estimated by OLS with standard errors are in parentheses under coefficient estimates clustered by sector. The dependent variable is the interview score for process innovation. CO_2 intensity data are derived from the CITL database while employment is taken from ORBIS. All other variables are derived from the interviews. Noise controls include interviewer, country, time, day and month of the interview and manager background fixed effects. Stars indicate statistical significance level: ***=1%, **=5%, *=10%.

Table 5: Regressions of product innovation score

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dep. Variable.	Product Innovation Score								
Anticipation of ETS Stringency		0.225***	0.188**	0.211***	0.204**				0.172**
		(0.078)	(0.076)	(0.072)	(0.080)				(0.078)
ETS Stringency in Phase 2						0.053	0.058	0.034	
						(0.048)	(0.051)	(0.065)	
CO_2 Price expectation by 2020		0.078	0.010	0.003	-0.043				-0.047
$\ln(CO_2\ Price)$		(0.098)	(0.090)	(0.094)	(0.157)				(0.150)
CO_2 Intensity in 2008			0.032	-0.007	-0.033	0.040	0.013	-0.001	-0.048
$\ln(CO_2/EMP)$			(0.044)	(0.046)	(0.050)	(0.042)	(0.045)	(0.044)	(0.047)
Multinational Enterprise			0.284**	0.237*	0.396*	0.299**	0.260**	0.448**	0.321
			(0.128)	(0.125)	(0.208)	(0.124)	(0.121)	(0.199)	(0.199)
R&D Intensive Facility			0.242**	0.260**	0.103	0.234**	0.252**	0.107	0.094
			(0.109)	(0.104)	(0.125)	(0.114)	(0.105)	(0.130)	(0.123)
Employment			0.152***	0.144***	0.085	0.171***	0.161***	0.122*	0.049
ln(emp)			(0.046)	(0.043)	(0.069)	(0.043)	(0.045)	(0.073)	(0.065)
In ETS in Phase 2	0.437*	0.434*	0.662**	0.484**	.	0.268	0.072	.	.
	(0.228)	(0.221)	(0.268)	(0.233)	.	(0.534)	(0.571)	.	.
In ETS in Phase 3	0.249	0.154	0.130	0.392	.	0.204	0.439	.	.
	(0.324)	(0.384)	(0.391)	(0.391)	.	(0.329)	(0.352)	.	.
In ETS in Phase 2 and 3	-0.456	-0.686	-0.678	-0.926**	.	-0.533	-0.780*	.	.
	(0.429)	(0.445)	(0.411)	(0.396)	.	(0.398)	(0.395)	.	.
Process R&D Score									0.219***
									(0.065)
Observations	732	732	731	731	342	731	731	342	342
R2	0.30	0.32	0.36	0.20	0.27	0.36	0.19	0.25	0.30
Cluster	153	153	153	153	91	91	91	91	91
3 digit sector controls	yes	yes	yes	no	no	yes	no	no	no
Noise Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes

Notes: All columns estimated by OLS with standard errors are in parentheses under coefficient estimates clustered by sector. The dependent variable is the interview score for product innovation. CO_2 intensity data are derived from the CITL database while employment is taken from ORBIS. All other variables are derived from the interviews. Noise controls include interviewer, country, time, day and month of the interview and manager background fixed effects. Stars indicate statistical significance level: ***=1%, **=5%, *=10%.

4.3 Using process innovation as a control variable

Product innovation should be less affected by any confounding variation that might affect the relationship between stringency and innovation. This is because producing and researching the design of wind turbines, for example, does not necessarily generate knowledge that helps to reduce the emissions from producing wind turbines. Even so, we cannot rule out that there are complementarities in conducting process and product R&D. To account for that, Table 5 includes an additional column where we include process R&D as an additional regressor.[13] The future stringency relationship remains significant at 10% in column 9 and leads to an estimate comparable in size when including process R&D as an additional control variable.[14]

4.4 The effect of the EU Commission rules

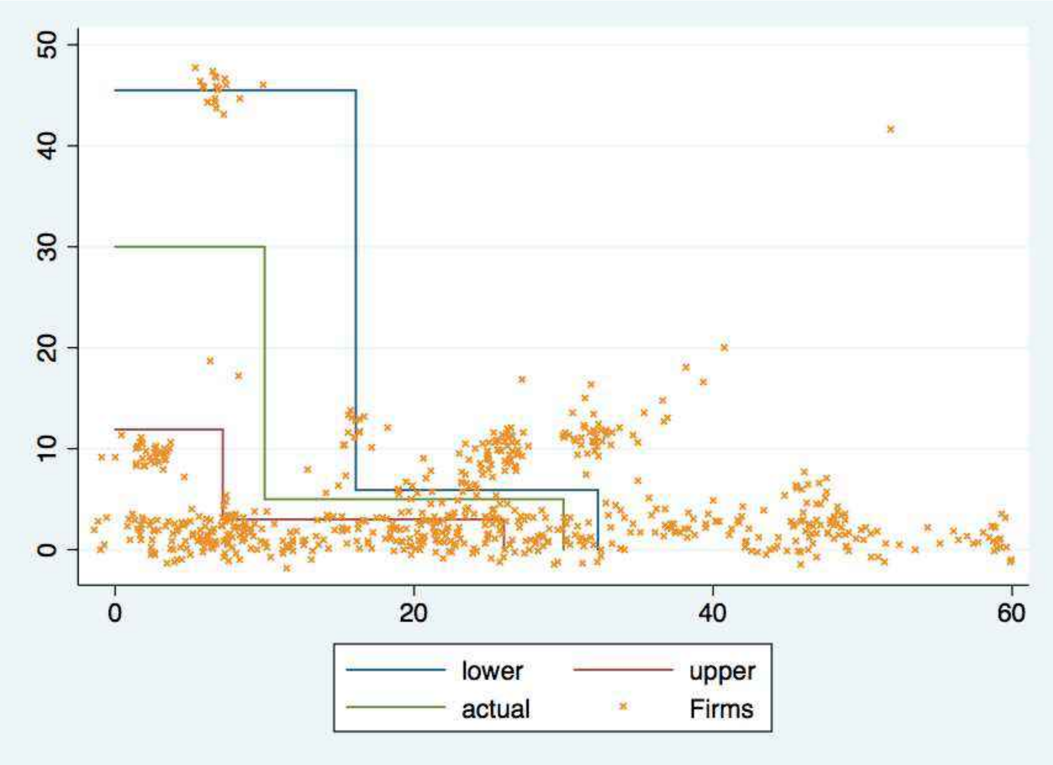
As a further check of the robustness of the relationship between stringency and innovation, we exploit the link between exogenous variations in free allowance allocation, rather than relying on the self-

[13] If variations in the cap are driving both process and product R&D, this would likely lead to a downward bias in the estimated coefficient on stringency. But if the "cap" effect is stronger for product R&D, we should still be able to detect an effect.

[14] The results of Tables 4 and 5 are robust to including a control of whether the firm is trading on the EU ETS or not.

reported stringency score.[15] As mentioned before, Phase III will see radical changes in the number of allowances that are allocated for free to firms. Under current proposals, the European Commission will exempt certain 4-digit industries from allowance auctioning, based on two statistics, trade intensity (TI) and CO_2 intensity (VaS)[16]. Firms in a 4-digit industry will be exempt if the industry's TI or VaS rates exceed 30%, or if the sector simultaneously exceeds a 10% threshold for TI and a 5% threshold for VaS. Figure 20 plots the firms in our sample in the VaS-TI space, along with a line (labeled "actual") indicating those thresholds.

Figure 20: Placebo and real thresholds



Notes: The Figure plots interviewed firms in the Value at Stake (y-axis) and Trade Intensity (x-axis) space according to the industry they belong to. The three lines correspond to the EU criteria for exemption of auctioning in Phase III and to two placebo threshold lines used in our analysis.

However, in Tables 6 and 7, we examine whether there is a discrete jump in both the reported expected stringency as well as innovation as we move over the thresholds implied by the European Commission criteria[17]. We also test if such discrete jumps are a feature of our data rather than the cause of exemptions from auctioning, by defining two "placebo" thresholds, which are also indicated in Figure 20. One threshold is slightly lower, the other slightly higher than the actual threshold. We experimented with a range of values here. The specific lines in Figure 20 are defined so as to ensure that 5% of firms fall within the band on either side of the different cut-off values. Let us consider first the regression results reported in Table 6, where future stringency – derived from our survey - is the

[15] Of the three factors underlying a firm's perception of stringency (see Section 3.5.2), we focus here on point (ii), the amount of permits the firm receives for free.

[16] The Value at Stake is defined as the ratio between the sum of the direct and indirect costs of full auctioning and the gross value added of a sector. The direct costs are calculated as the value of direct CO_2 emissions (using a proxy price of €30/t CO_2), and the indirect costs capture the exposure to electricity price rises.

[17] It is easy to think of reasons why trade and energy intensity might be correlated with the degree of innovation a firm is undertaking, irrespective of these criteria. Indeed, in Figure 21 we find that there is an inverse u-shaped relationship with respect to energy intensity for both product and process innovation.

dependent variable. In column 1, we include indicator variables that are equal to 1 if a firm exceeds any of these thresholds as explanatory variables. We see that there is a negative and significant coefficient for exceeding the actual threshold ("Exempt after 2012") and a positive coefficient for exceeding the upper threshold. In column 2, we include trade intensity (TI) and CO_2 intensity (VaS) in addition as explanatory variables. This has little effect on the threshold parameters. As we include quadratic terms, however, in column 3, the actual threshold effect becomes stronger and more significant, whereas the placebo effect becomes smaller and loses significance.[18] Moreover, we find in column 4 that there is no such threshold effect when looking at the current stringency score.

Table 6: What drives expectations?

Dependant Variable	(1) Expected Stringency Score	(2) Expected Stringency Score	(3) Expected Stringency Score	(4) Current Stringency Score
Exempt after 2012	-0.178	-0.246	-0.357	-0.242
	(0.190)	(0.218)	(0.233)	(0.413)
Placebo Exempt (lower)	-0.185	-0.069	-0.033	-0.206
	(0.134)	(0.183)	(0.196)	(0.317)
Placebo Exempt (upper)	0.353**	0.389**	0.318	-0.352
	(0.177)	(0.195)	(0.209)	(0.432)
Sectoral CO_2 Intensity (VaS)		0.285	3.414*	8.985***
		(0.585)	(2.004)	(3.106)
Sectoral Trade Intensity (TI)		-0.333	0.067	3.577
		(0.581)	(1.551)	(2.207)
VaS x VaS			-4.129*	-13.177***
			(2.139)	(3.862)
VaS x TI			-3.423	-7.750*
			(2.648)	(4.158)
TI x TI			0.025	-3.050
			(1.632)	(1.866)
Firm level CO_2 Intensity	0.138***	0.122***	0.110**	0.022
[$\ln CO_2$/EMP]	(0.034)	(0.041)	(0.044)	(0.052)
Multinational	0.323**	0.329**	0.312**	-0.070
	(0.127)	(0.126)	(0.129)	(0.172)
Site does R&D	-0.025	-0.019	-0.042	-0.048
	(0.149)	(0.152)	(0.151)	(0.145)
Employment [lnEMP]	0.162***	0.162***	0.163***	0.079
	(0.052)	(0.053)	(0.050)	(0.050)
Share of Competitors outside EU	0.181	0.186	0.214	0.079
	(0.169)	(0.178)	(0.173)	(0.249)
Observations	342	342	342	342
R2	0.26	0.26	0.27	0.17

Notes: All columns estimated by OLS with standard errors are in parentheses under coefficient estimates clustered by sector. The dependent variable is the interview score for expected stringency in columns (1) to (3) and for current stringency of EU ETS in column (4). Sectoral CO_2 intensity and trade intensity are derived from EUROSTAT data. CO_2 intensity data are derived from the CITL database while employment is taken from ORBIS. All other variables are derived from the interviews. Stars indicate statistical significance level: ***=1%, **=5%, *=10%.

Table 7 shows the results from similar regressions for the innovation variables. We find a negative point estimate of passing the actual threshold for process innovation, but it is not statistically significant at conventional levels. On the other hand, we find a very clear and statistically significant threshold effect for product innovation. The coefficient estimate implies that passing the threshold for free allowance allocation implied by the EU criteria leads to a drop in innovation on the order of 1 score point, on our score scale ranging from 1 to 5. As this corresponds roughly to 1 standard deviation, we conclude that the effect of stringency on product innovation is also economically significant. In column 5, we see that this result is robust to including only the actual threshold. Column 6 reports negative point estimates for the placebo threshold when the actual threshold is excluded from the regression. This reflects bias from omitting the relevant threshold as well as more noisy estimates, as the actual threshold is measured with error. Figure 21 illustrates the results of the

[18] We also experimented with higher order terms, which gave similar results.

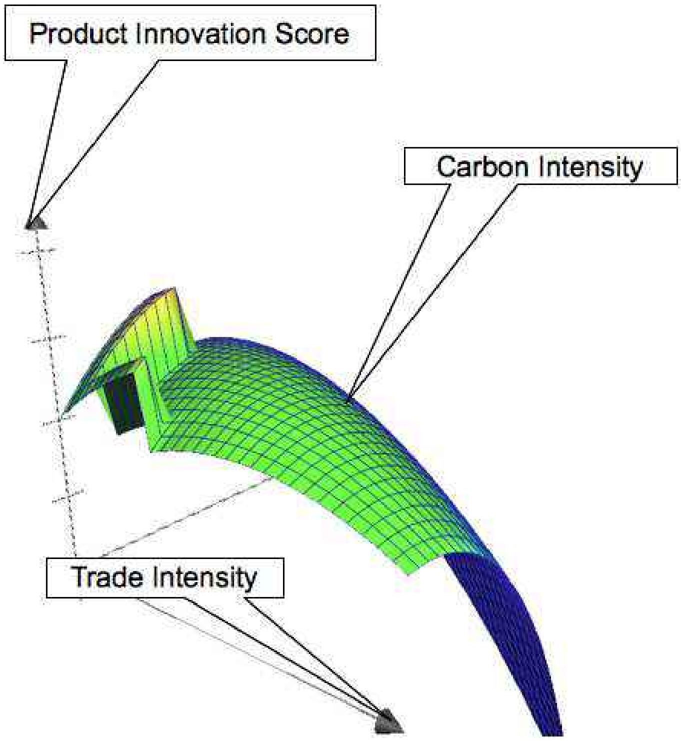
regression in column 5: there is a clear discontinuity in product innovation implied by the thresholds that define free allocation of allowances.

Table 7: The effect of exemptions on innovation

	(1)	(2)	(3)	(4)	(5)	(6)
Dependant Variable	Process Innovation Score		Product Innovation Score			
Exempt after 2012	-0.294	-0.301	-1.106**	-1.229**	-0.927***	
	(0.291)	(0.305)	(0.454)	(0.468)	(0.340)	
Placebo Exempt (lower)	0.445**	0.390*	0.249	0.255		-0.240
	(0.194)	(0.226)	(0.188)	(0.256)		(0.340)
Placebo Exempt (upper)	0.120	0.195	0.664	0.424		-0.212
	(0.288)	(0.299)	(0.521)	(0.513)		(0.404)
Sectoral CO_2 Intensity (VaS)	0.393	0.696	0.666	5.237	6.475*	2.498
	(0.740)	(2.501)	(0.560)	(3.439)	(3.517)	(3.617)
Sectoral Trade Intensity (TI)	-0.716	-1.964	-0.140	2.244	3.946*	2.238
	(0.432)	(1.754)	(0.609)	(2.250)	(2.284)	(2.285)
VaS x VaS		-1.563		-5.155	-6.642	-2.710
		(3.312)		(4.303)	(4.335)	(4.680)
VaS x TI		4.299		-7.068*	-7.297*	-4.131
		(4.073)		(3.628)	(3.994)	(3.782)
TI x TI		1.457		-1.968	-3.322	-2.285
		(1.688)		(2.101)	(2.285)	(2.193)
Firm level CO_2 Intensity	0.098	0.094	0.032	0.013	0.009	0.010
[$lnCO_2/EMP$]	(0.062)	(0.063)	(0.056)	(0.055)	(0.056)	(0.059)
Multinational	0.446*	0.423*	0.564***	0.547***	0.520**	0.530**
	(0.233)	(0.240)	(0.191)	(0.201)	(0.202)	(0.211)
Site does R&D	0.041	0.046	0.173	0.140	0.128	0.133
	(0.171)	(0.174)	(0.133)	(0.130)	(0.133)	(0.125)
Employment [lnEMP]	0.192***	0.187***	0.112	0.113	0.117	0.120
	(0.064)	(0.064)	(0.068)	(0.069)	(0.071)	(0.074)
Share of Competitors outside EU	0.288	0.338*	0.176	0.178	0.186	0.182
	(0.194)	(0.202)	(0.246)	(0.231)	(0.229)	(0.234)
Observations	342	342	342	342	342	342
R^2	0.28	0.28	0.24	0.25	0.25	0.22

Notes: All columns estimated by OLS with standard errors are in parentheses under coefficient estimates clustered by sector. The dependent variable is the interview score for process innovation in columns (1) to (3) and for product innovation in column (4). Sectoral CO_2 intensity and trade intensity are derived from EUROSTAT data. CO_2 intensity data are derived from the CITL database while employment is taken from ORBIS. All other variables are derived from the interviews. Stars indicate statistical significance level: ***=1%, **=5%, *=10%.

Figure 21: Discontinuity in Product Innovation



Notes: The figure gives a graphical impression of the regression results in column 5 of Table 7. The horizontal plane represents the CO_2 and Trade Intensity Space. The vertical axis measures the innovation score. We see that innovation responds to both Trade and CO_2 intensity with a positive linear and negative quadratic form. The figure shows the discontinuous decline in innovation that is implied by the thresholds which allow for free allocation of allowances.

In sum, we find robust evidence that product innovation responds to the expected stringency of the EU ETS. There is no clear evidence that the same is true for process innovation. An explanation for this could be that having to pay for all required emissions allowances has an important signaling function for companies in drawing the attention of more senior management levels to the issue of emissions. It is only then that firms would take the more strategic decision to engage in product lines that are climate-change related, as opposed to process innovation, which is arguably more gradual. In such a scenario there could be information barriers that prevent senior management from seeing these opportunities unless the issuance of tight, company-specific emissions caps forces them to focus on climate change issues.

5 Conclusion

This paper investigates climate-change related investment behavior among manufacturing firms in Europe on the basis of approximately 800 interviews with managers in six European countries.

We start by looking at the implementation of various measures related to the reduction of GHG emissions. We find that a large proportion of firms are pursuing some measures to reduce GHG emissions. For a majority of these (more than 60%), this includes energy- and carbon-saving measures related to their machinery and core processes. Looking at climate-change related innovation, we find that most (70%) firms are equally engaged in formal or informal R&D with the aim of curbing emissions and/or energy consumption. A smaller proportion (40%) is also pursuing “Clean product innovation”; i.e. R&D with the aim of developing products that can help customers to reduce their emissions. Almost all firms that report product R&D also report process R&D. We find that firms require, on average, a payback time of four years for investment in energy-saving measures. However, this figure varies widely between firms. Firms at the 90th percentile allow for more generous payback time of seven years, whereas firms at the 10^{th} percentile require 1.5 years. This variation is significantly correlated with the pursuit of process innovation by firms.

With regard to behavior within the EU ETS, we find that about 30% of firms participate only passively in the EU ETS; i.e. they do not consider carbon allowances as a financial asset that could provide opportunities. Rather, they see the EU ETS as something they merely need to comply with. While there are significant differences in EU ETS engagement between sectors, any differences between countries are not significant.

In line with this observation, it appears that the majority of EU ETS participants does not trade on the EU ETS market. Some of these firms do not need to trade because their emissions correspond to their allowance allocations. There is, however, concern that some firms do not make their allowances available despite possessing an excess supply. We find such an effect: on average firms start to sell only if they have an excess supply of 5,000 to 10,000 allowances. The total number of excess allowances held by firms below the trading threshold is rather small, at less than 10% of all excess allowances.

Firms expect future carbon prices to be considerably higher than current levels in the EU ETS, averaging €40 in 2020. Compared to the current 2^{nd} trading period, firms expect the imposition of tighter caps for the post-2012 EU ETS period. Whereas in Phase II 40% of firms reported that the EU ETS cap imposed on them was not binding, this proportion reduces to less than 10% for the post-2012 period. Firms that expect a more stringent EU ETS cap in Phase III are more likely to engage in product innovation. Such a correlation could potentially imply that in a trading system the allocation of emissions allowances might not be independent of other real factors, such as the investment in R&D.

We examine this hypothesis further by examining whether there is a discontinuity in innovative activity at the thresholds implied by the European Commission criteria for exemptions from auctioning post-2012. We find that firms that narrowly qualified for exemption from auctioning were conducting significantly less product innovation than firms that narrowly missed being exempted from auctioning. This finding is consistent with the hypothesis that having a tight carbon budget has an important signaling effect for firms in that it draws the attention of higher levels of management to the matter of GHG emissions. This in turn might be the trigger of the decision to engage in climate-change related product R&D. On the whole, our results support the view that allocating fewer allowances for free would lead to a stronger innovation response in an otherwise identical emissions trading system.

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Annex: Questionnaire

Questions	Values	Coding description
I. Introduction		
1. A bit about your business		
(a) Is your firm a multinational? If yes, where is the headquarters?	no, list of countries, dk, rf	"No", if not a multinational; country where headquarters is located if a multinational
(b) On how many production sites do you operate (globally)?	number, dk, rf	Number of sites globally (approximate if unsure)
(c) How many of these sites are situated in the EU?	number, dk, rf	Number of sites in the EU
(d) How many of these sites are situated in the UK/B/FR/...?	number, dk, rf	Number of sites in current country
2. A bit about you		
(a) Job title	text	
(b) Tenure in company	number, rf	
(c) Tenure in current post	number, rf	
(d) Managerial background	commercial, technical, law, other	
3. EU ETS involvement		
As you might know, the European Union Emissions Trading System (referred to as EU ETS, hereafter) is at the heart of European climate change policy. (a) Is your company (or parts thereof) regulated under the EU ETS? (b) Since when?	no, list of years 2005-2009, yes dk year, dk, rf	
(c) How many of your European business sites are covered by the EU ETS?	number, dk, rf	
4. Site location		

<table>
<tr><th>Questions</th><th>Values</th><th colspan="2">Coding description</th></tr>
<tr><td>For single plant firms and interviewees based at a production site:
Could you tell me the postcode of the business site where you are based?
For multi-plant firms where the interviewee is located at a non-production site:
Some of the questions I am going to ask you next are specific to a production site within your firm. Please choose a particular production site and answer my questions for the particular site throughout the interview. The site should be the one you know best, the largest one, or the one nearest to you. If you are in the EU ETS, please pick a site covered by the EU ETS. Could you tell me the postcode of the chosen site?</td><td>text</td><td colspan="2">Records the postcode</td></tr>
<tr><td colspan="4">II. Impact of EU ETS</td></tr>
<tr><td colspan="4">5. EU ETS stringency (If not an EU ETS firm, continue with question 9)</td></tr>
<tr><td rowspan="3">(a) How tough is the emissions cap/quota currently imposed by the EU ETS on your production site?
(b) Can you describe some of the measures you put in place to comply with the cap?</td><td rowspan="3">1-5, dk, rf, na</td><td>Low</td><td>Cap is at business as usual.</td></tr>
<tr><td>Mid</td><td>Some adjustments seem to have taken place, however nothing which led to fundamental changes in practices; e.g. insulation, etc.</td></tr>
<tr><td>High</td><td>Measures which led to fundamental changes in production processes; e.g. fuel switching; replacement of essential plant and machinery.</td></tr>
<tr><td rowspan="2">(c) What is the annual cost burden of being part of the EU ETS?
For example, monitoring, verification and transaction costs; the cost of buying permits or reducing emissions.
If the manager does not understand the question:
Imagine your installation was not part of the EU ETS this year, what cost saving would your firm do?</td><td>number</td><td colspan="2">Absolute number</td></tr>
<tr><td>percentage</td><td colspan="2">Or percentage of annual operating cost</td></tr>
<tr><td colspan="4">6. EU ETS management</td></tr>
<tr><td>Ask only multi-plant firms:
Is EU ETS compliance managed on the production site or</td><td>site, other site, national firm, European firm, dk, rf, na</td><td colspan="2"></td></tr>
</table>

Questions	Values	Coding description
elsewhere?		
7. ETS trading		
(a) In **March** of this year (i.e. **before** the compliance process), what was your allowance position on this site? (b) Were you short or long in allowances?	long, short, balanced, dk, rf, na	
	text	If the manager happens to mention the detailed number of allowances, make a note of it in this field.
(c) Before the compliance process in April, did you buy or sell allowances on the market or over the counter from other firms? (d) If not, why not?	buy, sell, both, no: only trading during compliance period, no: no need, no: image concerns, no: transaction costs, no: other, dk, rf, na	
(e) If yes, how frequently?	daily, weekly, monthly, quarterly, bi-annual, yearly, dk, rf, na	
(f) **In April this year**, what was your position after the compliance process?		
If answers "long": Did you bank permits for future years? Why?	banking to emit more in following years, banking to sell at a higher ETS permit price in future, banking dk why, long for pooling, dk, rf, na	Banking reason.
If answers "balanced/compliant" or "short": Did you borrow permits from next year's allowance? Why?	borrowing to emit less in following years, borrowing to buy at a lower ETS permit price in future, borrowing to be compliant, borrowing dk why, rf, dk, na	Borrowing reason. *Note: Only choose "borrowing to be compliant" if the manager is very short sighted and doesn't seem to understand he will eventually have to either emit less or buy permits*
If answers "short": Why did you remain short?	short for pooling, short and paid fine, other, rf, dk, na	Short reason.
	text	If “other”: why?
(g) Has this site exchanged emissions permits with other installations belonging to your company that are part of the EU ETS? (pooling)	yes, no, rf, dk, na	
8. Rationality of market behavior		

Questions	Values	Coding description	
(a) How do you decide how many permits to buy or sell or trade at all? (b) Did you base this decision on any forecast about prices and/or energy usage? (c) Did you trade permit revenue off against emissions-reduction costs in your planning on this issue?	1-5, dk, rf, na	Low	Take their permit allocation as a target to be met as such and do not take into account the price of permits or the cost of abatement. Just sell if there is a surplus or buy if there is a deficit.
		Mid	Are in the process of learning how the market works and in the first years did not have any market driven attitude, but now have someone in charge of managing the ETS so as to minimize compliance cost. This person has experience in financial markets and sometimes interacts with the production manager.
		High	Company has a thorough understanding of the site-specific CO2 abatement cost curve. Trading is used as a tool to reduce compliance cost and to generate extra revenues from excess abatement. Moreover, company forms expectations about permit price and re-optimizes abatement choice if necessary. Trader resorts to futures and derivatives to manage ETS permits as a financial asset.
9. Anticipation of Phase III			
(a) Do you expect to be part of the EU ETS from 2012 onwards? *If not, continue with question 10*	yes, no, dk, rf, na		
(b) How stringent do you expect the next phase of the EU ETS (from 2012 to 2020) to be? (c) Will it be tough for your firm to reach such a target? Can you describe some of the measures you would have to put in place? (d) Do you believe the allowances will be distributed through an auctioning mechanism? (e) Is it likely that sanctions for non-compliance will become more stringent?	1-5, dk, rf, na	Low	Cap for phase III is anticipated to be comparable to business as usual. The manager believes there will be no additional sanctions and that they will receive the permits for free.
		Mid	Phase III is likely to trigger some adjustments, however nothing that will lead to fundamental changes in practices. Only a small part of permits will be auctioned and sanctions are not expected to be very high.
		High	The presence of strong sanctions, extensive use of auctioning and more stringent targets in Phase III is anticipated. It is likely to imply the adoption of measures which will lead to fundamental changes in production processes. It might also imply the closure of the plant, or redundancy of more than 20% of employment.
(f) Do you expect to transfer unused (banked) ERUs or CERs from Phase II to Phase III ?	EUAs, ERUs, CERs, EUAs and ERUs, EUAs and CERs, ERUs		

Questions	Values	Coding description	
Note: ERUs are Emission Reduction Units stemming from Joint Implementation projects. CERs are Certified Emission Reductions stemming from Clean Development Mechanism projects.	and CERs, all three, no, dk, rf, na		
10. Awareness			
(a) Are climate-change topics discussed within your business? Can you give examples? (b) Are climate-change related issues formally discussed in management meetings? Can you give examples? (c) Do your strategic objectives mention climate change? (d) Did you commission reports or studies on how climate change will affect your business?	1-5, dk, rf, na	*Note: Give minimum score of 3 to ETS firms and probe directly for 4 or 5, skipping (a) and (b).*	
		Low	Don't know if threat or opportunity. No awareness.
		Mid	Some awareness backed up by evidence that this is being formally discussed by management.
		High	Evidence that climate change is an important part of the business strategy.
Mentioned positive impact:	yes, no		
III. Prices			
11a Energy price expectations			
By how many percent do you expect energy prices to go up or down by 2020?	percentage, dk, rf	Expected price change in percent of today's price. *Note: This price includes the effect of current and future climate-change policies on the energy price.*	
	percentage, dk, rf	Upper bound on expected price change – record only if interviewee mentions it.	
	percentage, dk, rf	Lower bound on expected price change – record only if interviewee mentions it.	
11b Carbon price expectations			
(a) As you might know, the EU has committed to reducing greenhouse gas emissions by 20%-30% over the next decade. What price do you expect to pay for emitting one tonne of CO2 in 2020?	percentage, dk, rf	Expected price in Euros per tonne of CO2.	
	percentage, dk, rf	Or expected price change in percent of today's price.	
	yes, no, rf, dk	Knows today's price of CO2.	
(b) What price do you expect in the worst-case scenario?		Upper bound in Euros per tonne of CO2.	
(c) What price do you expect in the best-case scenario?		Lower bound in Euros per tonne of CO2.	
12. Future impact of carbon pricing			

Questions	Values	Coding description	
(a) Do you expect that government efforts to put a price on carbon emissions will force you to outsource parts of the production of this business site in the foreseeable future, or to close down completely?	1-5, dk, rf	Low	No impact of this kind.
		Mid	Significant reduction (>10%) in production/employment due to outsourcing.
		High	Complete closedown.
(b) What carbon price do you associate with this scenario?(Assume that you would have to pay for all allowances.) *Note: The price relates to the scenario given under (a). If answered "no impact" under (a), skip this question.*	number, dk, rf, na	Euros per tonne	
(c) How would your answer to the previous questions change, if you received a free allowance for 80% of your current emissions? *Note: If answered "no impact" under (a), skip this question.*	1-5, dk, rf, na	Low	No impact of this kind.
		Mid	Significant reduction (>10%) in production/employment due to outsourcing.
		High	Complete closedown.
(d) *Note: Only ask if answered "no impact" under (a).* At what carbon price level would you be forced to close your plant down? ***If the manager has no idea or says it would need to be very high, try different prices, starting high, f****or example:* If you had to pay €200/tonne of carbon, would you need to close down?	number, dk, na	**Euros per tonne**	
(e) How did you reach this conclusion? (f) How concrete are the plans for outsourcing or closure?	1-5, dk, rf, na	Low	Gut feeling of the manager.
		Mid	Response is based on a plausible argument. For example, interviewee discusses available technological options and associated cost and relates them to profit margins.
		High	Commissioned a detailed study of abatement options and associated cost (in-house or external).
(g) What fraction of an energy price or carbon price increase can you pass on to your customers?	percentage, dk, rf		
IV. Competition and customers			
13. Competitors			
(a) Can you tell me the number of firms in the world which compete with you in one or more local markets? *Note: For multi-product multi-plant firms refer to the market for the products created on the current site referred to during*	number, dk, rf		

Questions	Values	Coding description	
this interview. For instance, for multi-plant firms start the question with "For the products produced at the production site, can you tell me ..."			
(b) How many of them are located within the EU?	number, dk, rf		
(c) How many of them are located in your country?	number, dk, rf		
(d) Location of main competitor (country)	list of countries, dk, rf, na		
(e) Do you know in which country your main competitor does most of its production?	same, EU, non-EU, list of countries, dk, rf, na		
14. Location of Customers			
(a) Share of sales exported (to the EU and the rest of the world)	percentage, dk, rf		
(b) Share of sales exported to EU countries	percentage, dk, rf		
(c) Are your products sold mainly to consumers or to other businesses?	B2B, final customer, dk, rf		
15. Customer pressure			
(a) Are your customers concerned about your GHG emissions? (b) How do they voice this concern? (c) Do your customers require hard data on your carbon emissions?	1-5, dk, rf	Low	"B2C" - Not aware that emissions performance is of significant concern to consumers of their product. "B2B" - Not aware that businesses they supply to are concerned about the emissions of the plant; quality and price are the only considerations.
		Mid	"B2C" - The business is aware of the importance of climate-change issues in general and so are conscious that their customers may consider GHG performance to be important, although they do not expect or require data as proof. "B2B" - Customers set ISO 14001 as a precondition to suppliers. Evidence of environmental compliance is requested, but details of emissions figures are not required.
		High	"B2C" - Being seen to reduce GHG emissions is thought to be important in the purchasing decisions of the firm's consumers. This has been determined by market research or consumers have voiced their concern through other means. Customers also ask for certified data on emissions during production or usage. A customer-friendly system to recognize the best products in terms of energy efficiency is

Questions	Values	Coding description	
			often available in the market (e.g. EU energy efficiency grade for home appliances). "B2B" - Customers ask for evidence of external validation of GHG figures. Customers request information on carbon emissions as part of their own supply chain carbon auditing. Customers conform to PAS 2050 or other national standard in carbon foot-printing and so require detailed information on a regular basis.
16 Climate change related product innovation			
(a) Globally, is your company currently trying to develop new products that help your customers to reduce GHG emissions? (b) Can you give examples? (c) What fraction of your Research & Development funds is used for that? (Less than 10%, more than 10%?)	1-5, dk, rf	Low	No efforts to develop climate change related products.
		Mid	Some efforts but it is not the main objective of the firms R&D efforts.
		High	The firm is focusing all product R&D efforts on climate change.
V. Measures			
17. Energy monitoring			
(a) How detailed is your monitoring of energy usage? (b) How often do you monitor your energy usage? Since when? (c) Describe the system you have in place.	1-5, dk, rf	Low	No monitoring apart from looking at the energy bill.
		Mid	Evidence of energy monitoring as opposed to looking at the energy bill, i.e. there is some consciousness about the amount of energy being used as a business objective. However, discussions are irregular and not part of a structured process and are more frequent with price rises. Not more than quarterly monitoring of energy.
		High	Energy use is measured and monitored constantly and is on the agenda in regular production meetings. Energy use in the plant is divided up in space (by production line, machine or similar) and monitored over time (daily, hourly or continuously). The amount of energy rather than the cost is focused on.
	2000 and earlier, list of years 2001-2010, dk, rf, na	Start date (put “na” if score is “1”)	
18. Targets on energy consumption for management			

Questions	Values	Coding description	
(a) Do you have any targets on energy consumption which management has to observe? (e.g. kWh of electricity)	no targets, relative quantity targets, absolute quantity targets, absolute and relative quantity targets, only expenditure targets, dk, rf	Type	
(b) Can you describe some of the challenges you face in meeting the targets? (c) How often do you meet these targets? Do you think they are tough? *Note: If the manager replies they have EU ETS/CCA targets, ask "have these been translated into internal targets for management?"*	1-5, dk, rf	Low	No targets.
		Mid	Targets exist but seem easy to achieve.
		High	Evidence that targets are hard to achieve. Detailed.
(d) By approximately how much does this require reducing your current energy consumption in the next 5 years (10%, 25%, 50%)? *e the timetable for the target (e.g. 5 years or other number given by interviewee).*	percentage, dk, rf, na		
	number, dk, rf, na	Horizon (number of years)	
(e) Since when do you have these targets?	2000 and earlier, list of years 2001-2010, dk, rf, na		
19. GHG monitoring			
(a) Do you explicitly monitor your GHG emissions? Since when? (b) How do you estimate your GHG emissions? (c) Are your GHG estimates externally validated?	1-5, dk, rf	Low	No specific GHG monitoring.
		Mid	Detailed energy monitoring with clear evidence for carbon accounting (at least firm level). Manager is aware that energy figures need to be scaled by carbon intensity.
		High	Carbon accounting of both direct and indirect emissions (supply chain emissions). External validation of GHG figures.
	2000 and earlier, list of years 2001-2010, dk, rf, na	Start date (put “na” if score is “1”)	
20. Targets on GHG emissions for management			
(a) Do you have any targets on GHG emissions which management has to observe?	no targets, direct emissions, indirect and direct, dk, rf		

Questions	Values	Coding description	
(b) Can you describe some of the challenges you face in meeting the targets? (c) How often do you meet these targets? Do you think they are tough? *Note: If the manager replies they have EU ETS/CCA targets, ask: H*ave these been translated into internal targets for management?	1-5, dk, rf	Low	No targets for GHG emissions.
		Mid	There is some awareness of the contribution of different energy sources and production processes to emissions, but this is a secondary consideration to cost focused energy targets. There is some degree of difficulty in the targets.
		High	There are separate targets for GHGs, distinct from energy use. GHG emissions are a KPI (Key Performance Indicator) for the firm. The contribution of each energy source and the production process to GHG emissions is known and suggested improvement projects for the production are assessed on their potential impact on carbon as well as energy efficiency.
By approximately how much do these targets require you to reduce your emissions in the next 5 years (10%, 25%, 50%) compared to their current level? *e the timetable for the target (e.g. 5 years or other number given by interviewee)*	percentage, dk, rf, na		
	number, dk, rf, na	Horizon (number of years)	
(e) When did you start having targets on GHG emissions?	2000 and earlier, list of years 2001-2010, dk, rf, na		
21. Target enforcement			
(a) What happens if energy consumption or GHG emissions targets are not met? (b) Do you publicize targets and target achievement within the firm or to the public? Can you give examples? (c) Are there financial consequences in case of non-achievement? (d) Is there a bonus for target achievement?	1-5,dk,rf	Low	No targets or missing targets do not trigger any response.
		Mid	Both target achievement and non-achievement are internally and externally communicated.
		High	Target non-achievement leads to financial consequences internally and/or externally; including penalties, e.g. staff does not get bonus.
22. Emission-reducing measures			

Questions	Values	Coding description
(a) Can you tell me what measures you have adopted in order to reduce GHG emissions (or energy consumption) on this site? DO NOT PROMPT with the list if doesn't have an idea, rather ask: Have you bought any new equipment, or have you changed the way you produce?	List of tick boxes	<u>I. Heating and cooling:</u> 1- Optimized use of process heat 2- Modernization of cooling/refrigeration system 3- Optimization of air conditioning system 4- Optimization of exhaust air system and/or district heating system
		<u>II. More climate-friendly energy generation on site:</u> 1- Installation of combined heat and power (CHP) plant / cogeneration 2- Biogas feed-in in local combined heat and power plant or domestic gas grid 3- Switching to natural gas 4- Exploitation of renewable energy source
		<u>III. Machinery:</u> 1- Modernization of compressed air system 2- Other industry-specific production process optimization/machine upgrade 3- Production process innovation
		<u>IV. Energy management:</u> 1- Introduction of energy management system 2- Submetering / upgrade of an existing energy management system 3- (External) Energy audit 4- Installation of timers attached to machinery 5- Installation of (de-)centralized heating systems
		<u>V. Other measures on production site:</u> 1- Modernization of lighting system 2- Energy-efficient site extension/improved insulation/introduction of building management 3- Employee awareness campaigns and staff trainings 4- Non-technical reorganization of production process 5- Installation of energy-efficient IT-system 6- Improved waste management/recycling
		<u>VI. Beyond production on site:</u> 1- Introduction of climate-friendly commuting scheme 2- Consideration of climate-related aspects in investment and purchase decisions 3- Consideration of climate-related aspects in distribution 4- Customer education program

Questions	Values	Coding description
		5- Participation in carbon offsetting schemes
(b) Which one of these measures achieved the largest carbon saving?	measure code	*Fill in the code corresponding to the measure in (a) (e.g. II-4 for "Exploitation of renewable energy source").*
(c) By how much did this measure reduce your total energy consumption?	percentage, dk, rf, na	
(d) By how much did this measure reduce your total GHG emissions?	percentage, dk, rf, na	
(e) What motivated the adoption of these measures?	EU ETS, energy cost saving / high profitability, pollution reduction, reputation, customer pressure, employee initiative, public investment support, compliance with regulation, compliance with expected future regulation, other, dk, rf, na	Main motivation (select only ONE)
	text	Other motivation (if not in tick boxes, or second)
(f) How did you learn about this measure?	consultant, government, customer, supplier, employee, R&D project, competitor, other, dk, rf, na	Tick more than one option, if different sources mentioned
(g) When did you implement this measure?	2000 and earlier, list of years 2001-2010, dk, rf, na	
VI. Innovation, barriers to investment and management		
23. Climate change related process innovation		

Questions	Values	Coding description	
(a) Do you dedicate staff time and/or financial resources to finding new ways of reducing the GHG emissions at your facility? Did you commission any studies for that purpose? (b) Can you give examples? (c) What fraction of your firm's global Research & Development funds is used for that? (less than 10%, more than 10%?) *Note: This does not include expenses for staff trainings or energy monitoring, but actual innovation.*	1-5, dk, rf	Low	No R&D resources committed to reducing GHG emissions.
		Mid	Evidence of R&D projects to reduce emissions.
		High	Evidence that this kind of R&D is an important component in the company's R&D portfolio (5 or higher).
24. Barriers to adopting energy-efficiency investments			
(a) Can you give one example of a measure to enhance energy efficiency which was considered, but eventually not adopted?	List of tick boxes	Same list as for question 22a.	
(b) Which payback time was required in the economic evaluation of this measure?	number, dk, rf, na	"Years"; if in months, put equivalent in years, e.g. record 6 months as 0.5.	
(c) Is this payback time longer or shorter than the one applied to non-energy related measures to cut costs?	1-5, dk, rf, na	Low	Longer, i.e. much less stringent
		Mid	Equal
		High	Shorter, i.e. much more stringent
(d) If different: why?	text		
(e) Was uncertainty about future prices or regulation important for the decision to reject?	no, yes_prices, yes_regulation, yes_both, dk, rf, na		
(f) What other factors were influential in the decision?	text		
(g) Has the current economic downturn affected your investment criteria for clean technologies? How?	no, favors clean, favors other, more stringent overall, less stringent overall, dk, rf, na		
25. Further reductions			
(a) By how much (in percentage points) could you - at current energy prices - further reduce your current GHG emissions without compromising your economic performance? (i.e. how much more emissions reduction could be achieved without increasing costs)	percentage, dk, rf		

Questions	Values	Coding description
(b) If so, why have you not implemented these measures yet?	text	
(c) What further GHG emissions reduction (in percentage points) would be technologically possible (although not necessarily at no extra cost)?	percentage, dk, rf	Notes: Assuming that production stays constant and that no processes are being outsourced. This should not include emissions reduction achieved by switching to renewable electricity. Include emissions reductions through combined heat and power however.
26. Manager responsible for climate change issues		
(a) At the management level, who is responsible for dealing with climate change policies and energy and pollution reduction in the firm nationally? What is the official job title? *Note: If several, ask for highest-ranking. If nobody, put title "no clear responsibility".*	text	Job title of the manager
(b) How far in the management hierarchy is this manager below the CEO? (figure out through sequential questioning if necessary)	CEO, number, no clear responsibility, dk, rf	No of people between CEO and Manager, e.g. if reports directly to CEO, put 0
(c) Has there recently been a change in responsibilities for climate change issues? When?	no change, list of years 2000-2010, yes dk year, dk, rf	
(d) How far in the management hierarchy was this manager below the CEO? (figure out through sequential questioning if necessary)	CEO, number, no clear responsibility, dk, rf	
	text	Record past manager title if mentioned, but do not prompt for it.
VI. Firm Characteristics		
27. Firm/Plant Details		

Questions	Values	Coding description
1 How many people are employed in the firm globally (including this country)? *Note: If a multinational, ask for the whole group's number.*	number, dk, rf	
2 How many people does the firm employ in your country?	number, dk, rf	
3 How many people are employed at the current site?	number, dk, rf	
4 Annual Energy Bill-Annual:	number, dk, rf	
		Do not ask, but in case interviewee does not know the absolute number and answers with one of the following:
	percentage, dk, rf, na	Energy cost as percentage of ***turnover***
	percentage, dk, rf, na	Energy cost as percentage of ***costs***
5 Total annual running costs (wage cost + materials, including energy):	number, dk, rf	
Answered (d) and (e) at the site level or at the company level?	site, company, na	
(f) Does your company purchase renewable power?	yes, no, dk, rf	*Note: Do not include electricity generated on site.*
(g) Does this site do any product R & D? *Note: Do not dwell on this question, make a judgment from first answer.*	yes, no, dk, rf	
(h) Is Marketing for your products done from this site? *Note: Do not dwell on this question, make a judgment from first answer.*	yes, no, dk, rf	
(i) Does this site have an environmental management system (ISO 14000)?	yes, no, dk, rf	

Questions	**Values**	**Coding description**	
VII. Country-specific policies			
UNITED KINGDOM			
UK.1 Participation in voluntary government climate change policies			
(a) Are you aware of voluntary government schemes to help businesses reduce GHG pollution? (b) Which ones? (c) Are you participating in any?	no, list of years 2001-2009, dk, rf, na	Carbon Trust Online Tools (Benchmarking Tools, Action Plan Tool) When?	
	no, list of years 2001-2009, dk, rf, na	Carbon Trust Energy Audit or Advice? (CTaudit)	
	no, list of years 2001-2009, dk, rf, na	Innovation grants from the Carbon Trust? When?	
	no, list of years 2001-2009, dk, rf, na	Carbon Trust Standard	
	no, list of years 2001-2009, dk, rf, na	Enhanced Capital Allowance scheme? (ECA)	
UK.2 Participation in climate change agreement			
(a) Is your company (or parts thereof) subject to a UK Climate Change Agreement? (b) Since when?	no, list of years 2001-2009, dk, rf, na		
(c) How stringent is the target imposed by the CCA? (d) Can you describe some of the measures you had to put in place to comply with the cap?	1-5, dk, rf, na	Low	No targets.
		Mid	Targets exist but seem easy to achieve.
		High	Evidence that targets are hard to achieve. Detailed description of serious problems in achieving targets.
((e) Did you buy or sell emissions rights via the UK ETS?	no because of image concerns, no because no capacity, no other, bought, sold, both, dk, rf, na		
BELGIUM			
B.1 Participation in industry agreements (accords de Branche/Bechmarkconvenanten) (a) Is your company (or parts thereof) subject to an industry agreement?	no, list of years 2001-2009, dk, rf, na		

Questions	Values	Coding description	
(b) Since when?			
(c) How stringent is the target imposed by the agreement? (d) Can you describe some of the measures you had to put in place to comply with the cap?	1-5, dk, rf, na	Low	No targets.
		Mid	Targets exist but seem easy to achieve.
		High	Evidence that targets are hard to achieve. Detailed description of serious problems in achieving targets.
B.2 Do you benefit from any tax reduction from the Federal government because of investments that reduce energy consumption/loss? If yes, when?	no, list of years 2001-2009, yes dk year. dk, rf, na		
B.3 **Brussels:** Have you had a grant for an energy audit or advice financed by the Brussels region? If yes, when? **Walloon:** Have you had any energy audit (AMURE) or advice financed by the Walloon region? If yes, when? **Flanders:** Have you received any advice or energy audit financed by VLAO (Vlaams Agentschap Ondernemen)? If yes, when?	no, list of years 2001-2009, yes dk year. dk, rf, na		
B.4 **Brussels:** Have you benefited from an investment subsidy from the Brussels region for improving your building's or production process's energy efficiency? If yes, when? **Walloon:** Have you had a grant from the energy fund of the Walloon region for improving your building's or production process's energy efficiency? If yes, when? **Flanders:** Have you received an ecological grant (Ecologipremeie) of the Flemish region for improving your building's or production process's energy efficiency? If yes, when?	no, list of years 2001-2009, yes dk year. dk, rf, na		
B.5 **Flanders:** Do you have a heat and power certificate from the Flemish region (warmtekrachtcertificaat)? If yes, since when?	no, list of years 2001-2009, yes dk year. dk, rf, na		
FRANCE			
F1. Are you part of the AERES (Association des entreprises pour la réduction de l'effet de serre) and have signed up to voluntary GHG emissions reductions? If yes, since when?	no, list of years 2001-2009, yes dk year. dk, rf, na		
F2. Have you had a grant for an energy audit or advice	no, list of years 2001-2009, yes		

Questions	Values	Coding description
financed by ADEME? If yes, when?	dk year. dk, rf, na	
F3. Have you benefited from a "FOGIME" guarantee for loans you have taken to invest into energy efficiency improvements or emissions reductions? If yes, when?	no, list of years 2001-2009, yes dk year. dk, rf, na	
F4. Have you benefited from a grant from ADEME for improving your building's or production process's energy efficiency ? If yes, when?	no, list of years 2001-2009, yes dk year. dk, rf, na	
GERMANY		
G.1 Renewable Energy Sources Act		
(a) In previous year, have you been granted a discount on your energy cost which reduces the energy cost apportionment embodied in the Renewable Energy Sources Act?	no, yes, dk, rf, na	
(b) Have you applied for the discount (also) in 2009?	no, yes, dk, rf, na	
(c) Did the certification process require you to upgrade your energy management system? *Note: Since 2009 the approval of the discount is subject to the certification of your energy management system by 30 June 2009.*	yes, no upgrade necessary, no had certificate before, dk, rf, na	
G.2 Public support programs		
Have you participated in public support programs aimed at saving energy or at reducing GHG emissions?	no, list of years 2001-2009, yes dk year. dk, rf, na	Climate initiative
	no, list of years 2001-2009, yes dk year. dk, rf, na	ERP Environment and Energy Efficiency Program
	no, list of years 2001-2009, yes dk year. dk, rf, na	Grant for independent energy audit from fonds for energy efficiency in SME
	no, list of years 2001-2009, yes dk year. dk, rf, na	Provision of cut-rate investment credit from fonds for energy efficiency in SME to implement identified energy-saving measures
	no, list of years 2001-2009, yes dk year. dk, rf, na	Support scheme of a federal state
	text	Other
HUNGARY		

Questions	Values	Coding description
H1. Have you received government support for any of your investments to reduce emissions or implement energy efficiency measures or increase the use of renewables? If yes, when?	no, list of years 2001-2009, yes dk year. dk, rf, na	Környezetvédelmi Alap Célelőirányzat
H2.(a) Have you received EU funds to support any of your investments to reduce□emissions or implement energy efficie□□□ m□□sur□□ o□ incr□□se□the □□e o□ ren□wables? If yes, when?	no, list of years 2001-2009, yes dk year. dk, rf, na	
(b) If yes, f□r which Operative□Progra□; which call for proposa□?	KEOP, KIOP, ERFA, dk, rf, na	
H3. Have you received funding from the Norwegian Fund for support? If yes, when?	no, list of years 2001-2009, yes dk year. dk, rf, na	EGT és Norvég Finanszírozási Mechanizmusok program
POLAND		
P.1 Do you use the sectoral information brochures published by the Ministry of Environment that include the information about the best available technologies for different economic activity? Since when?	no, list of years 2001-2009, yes dk year. dk, rf, na	
P.2 Have you ever taken a technological credit provided by the Technological Credit Fund? If yes. when?	no, list of years 2001-2009, yes dk year. dk, rf, na	
P.3 Have you ever been co-financed or have taken a preferential credit from the National Fund of Environmental Protection and Water Management, Bank of Environmental Protection and EkoFund? If yes, when?	no, list of years 2001-2009, yes dk year. dk, rf, na	
P.4 Have you ever benefited from the subventions and tax reductions from the government for environmental purposes? If yes, when?	no, list of years 2001-2009, yes dk year. dk, rf, na	
VIII. Post Interview		
Interview duration (mins)	number	Minutes
Interviewers' impression of interviewee's reliability	1-5, dk, rf	Low: Some knowledge about his site, and no knowledge about the rest of the firm. Mid: Expert knowledge about his site, and some knowledge about the rest of the firm. Expert knowledge about his site and the rest of the firm.

Questions	Values	Coding description	
		High	
Interviewee seemed concerned about climate change	1-5, dk, rf	Low	Not concerned.
		Mid	Somewhat.
		High	Very concerned.
Interviewee seemed skeptical about action on climate change	1-5, dk, rf	Low	Not skeptical at all.
		Mid	Somewhat skeptical.
		High	Very skeptical.
Mentioned other climate change related policies	text		
Complained a lot about high energy prices	no, a little, a lot		
Number of times interview needed to be rescheduled	number		
Seniority of interviewee	Director, VP/General Manager, Plant/Factory Manager, Manufacturing/Production Manager, (Environmental), Health & Safety Manager, Technician		
Age of interviewee *Note: Do not ask, guess!*	number		
Gender of interviewee	male, female		
Interview language	English, French, German, Dutch, Hungarian, Polish		