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Anatomy of a Paradox: Management Practices, Organisational Structure and Energy Efficiency

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Abstract
This paper presents new evidence on managerial and organizational factors that explain firm level energy efficiency and TFP. We interviewed managers of 190 randomly selected manufacturing plants in the UK and matched their responses with official business microdata. We find that 'climate friendly' management practices are associated with lower energy intensity and higher TFP. Firms that adopt more such practices also engage in more R&D related to climate change. We show that the variation in management practices across firms can be explained in part by organizational structure. Firms are more likely to adopt climate friendly management practices if climate change issues are managed by the environmental or energy manager, and if this manager is close to the CEO. Our results support the view that the "energy efficiency paradox" can be explained by managerial factors and highlight their importance for private-sector innovation that will sustain future growth in energy efficiency.

Keywords: climate policy, energy efficiency, firm behavior, management practices, manufacturing, microdata, organizational structure.
JEL Classifications: M20, M14, D22, Q41, Q54, Q58

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1 Introduction

The comeback of energy efficiency as a high-priority topic on policy and research agendas can be attributed to two factors. First, scientists have established a causal link between global climate change and the accumulation of manmade emissions of so-called greenhouse gases (GHG) in the atmosphere. Climate change constitutes a serious threat to ecosystems and to the productive base of economies around the globe (IPPC, 2007). Second, the global surge in the demand for energy, fueled by rapid industrial take-off and changing consumption patterns in emerging economies, has led to unprecedented increases in both the level and volatility of energy prices. As a result, investments in energy-saving technologies have become more attractive from a business point-of-view, both as a way of cutting running costs and as a hedging strategy. In addition, many governments have taken to providing incentives for such investments, be it for reasons related to climate-change or with the stated objective of reducing the dependency on energy imports.

The success of policies aiming to improve the efficiency and to lower the carbon intensity of energy use depends crucially on the policy maker's ability to predict how the business sector responds to different regulatory measures. This is important not only because this sector accounts for more than one third of GHG emissions in industrialized economies, but also because a large part of the research and development (R&D) that is expected to reduce emissions in the long run is carried out and paid for by private firms. Therefore, effective regulation must provide incentives for both short-run measures to improve energy efficiency *and* R&D investments leading to sustained efficiency growth in the future.

Clearly, any such regulation should be based on scientific evidence. Yet, researchers working in this area have struggled to make sense of the empirical oddity that firms seem to apply irrationally high discount rates when evaluating investments into energy efficiency. Put differently, firms appear to systematically reject energy efficiency upgrades in spite of a positive net present value that results when the "correct" risk-adjusted cost of capital is used to discount the payoff stream associated with the project. This phenomenon has been referred to as the "energy efficiency paradox" or the "energy efficiency gap" (e.g. Hausman, 1979; DeCanio, 1993; Jaffe and Stavins, 1994). While there is some evidence for the existence of a paradox, the underlying factors are not yet well understood. If the paradox is driven by frictions or market failures that public policy can address, then the dual objectives of climate change mitigation and energy security can be achieved by removing such frictions – possibly at little or no cost. The challenge remains to identify all the relevant barriers to energy efficiency improvements.

This study uses a unique combination of survey data and official microdata to shed light on this issue. Based on interviews with managers of 190 manufacturing firms in the UK we derive performance measures for the companies' practices in the areas of energy use and climate change. In addition, we gather independent performance data from both official and commercial sources for the firms in our sample. Based on the interview data alone, we document several aspects of firm behavior consistent with the energy efficiency paradox. For example, firms report that they could achieve substantial carbon savings without compromising on their performance. Moreover, firms use payback criteria that seem unreasonably short and sometimes discriminate against energy efficiency projects.

Using "hard" data on energy use and economic performance, we provide ample evidence that these and other management practices have immediate repercussions on firm performance. A summary index of climate friendly management practices is strongly positively associated with the firm's productivity and negatively so with its energy intensity. Moving from the 25th to the 75th percentile in the distribution of this index is associated with a 30% decrease in energy intensity, which corresponds to almost half of the standard deviation within sectors. We show that these results are driven by a number of specific management practices such as the implementation of targets for energy consumption or more lenient payback criteria for energy efficiency investments, as well as by investors demanding more climate friendly practices. Interestingly, we find energy efficiency to be more strongly associated with management practices than with climate policy measures that have been implemented in the UK.

In further analysis, we address two questions related to the energy efficiency paradox. First, we examine whether the mix of management practices in our sample is determined by organizational structure. We find that firms in which climate change issues are managed by the environmental or energy manager are more likely to adopt climate friendly management practices. Hierarchy has a non-monotonic effect, in that the closer this manager is to the CEO the more climate friendly practices are adopted, yet this is not true if the CEO is in charge of climate change issues. Second, we move beyond the energy efficiency paradox – which is about technology adoption – and analyze the relationship between management practices and climate friendly innovation. Climate friendly R&D is an important outcome measure in its own right as it has the potential to reduce emissions not only of the company conducting it (via process innovation) but also of the companies' customers (via product innovation). We show that several management practices are positively associated with climate friendly innovation. An important implication of this result is that some of the managerial factors that facilitate energy efficiency investments could also promote climate friendly innovation, thus leveraging their beneficial effect.

Our analysis contributes to the literature in several ways. First, it adds to a series of papers studying the "energy efficiency paradox" in the context of firm behavior (e.g. Ayres, 1994; DeCanio, 1993; Jaffe and Stavins, 1994).[1] The failure of firms to adopt profitable, energy-saving innovations has been attributed to market failures (Jaffe and Stavins, 1994) and to managerial factors such as short-run optimizing behavior or the lack of managerial resources and attention for cost-cutting projects outside the scope of the firm's main business(DeCanio, 1993). Case studies of energy efficiency programs have shown that firm characteristics influence the adoption decision even though they should not matter in a friction-less, neo-classical world (DeCanio and Watkins, 1998b; DeCanio, 1998; Anderson and Newell, 2004). This paper improves our understanding of the barriers to energy efficiency upgrades more generally as it exploits detailed data on managerial and organizational characteristics from a random sample of manufacturing firms. In addition, our analysis provides a deeper insight into the negative association between lean management practices and energy intensity found by Bloom et al. (2009), who did not have data on climate friendly management practices.

The paper also addresses the role of organizational structure for the adoption of new technologies or management techniques. In theoretical work by DeCanio and Watkins (1998a) and DeCanio et al. (2000), the speed of adoption depends to a large extent on the internal hierarchy of the firm, irrespective of the human capital and innate ability of the individuals who form it. Using tractable concepts of organizational structure and hierarchy we test this hypothesis in the context of the adoption of climate friendly management practices. What is more, the paper contributes to the empirical literature on environmental regulation and innovation (Jaffe and Palmer, 1997; Brunnermeier and Cohen, 2003; Johnstone, 2007), which thus far has produced very little

[1] The paradox has also be examined in the context of consumer choices (see Auffhammer et al., 2006, for a survey).

evidence about the drivers of climate friendly innovation at the firm level.[2]

Not least, our study contributes to the further development of data gathering and matching in this area. The principal obstacle to conducting a joint analysis of organizational structure, managerial practices, energy efficiency, productivity and innovative activity at the firm level is the lack of readily available data. Firm-level data on energy use is subject to strict confidentiality rules in most countries that collect them. While data on innovation is sometimes collected as part of specialized surveys, information on organizational structure and management practices are not reported in official statistics, let alone practices that pertain to climate change issues. Asking people about their motivations and behavior is a straightforward method of eliciting this information, but some precautions need to be taken to avoid that respondents give biased responses (Bertrand and Mullainathan, 2001). Bewley (1999, 2002) advocates the use of loosely structured interviews instead of questionnaires, particularly in areas where the divergence between observed behavior and theoretical predictions suggests that people's objectives are not understood or that the constraints are misrepresented. Research on the energy efficiency paradox as described in the literature fits this description well.[3] We thus adopt the method of "double-blind" telephone interviews developed by Bloom and van Reenen (2007), which minimizes known types of survey biases while preserving random sampling of the respondents. This approach reconciles survey techniques and empirical methods based on "revealed-preference" arguments by matching the survey data to "hard" data on firm performance, in our case to the ORBIS database and to confidential microdata maintained by the Office of National Statistics (ONS).

The remainder of the paper is organized as follows. The next section describes the data and the survey design in detail and explains its underlying philosophy. It also provides an overview of the survey responses and describes the linking to business performance data. Section 3 analyzes how energy efficiency and TFP correlate with management practices and policy variables measured in the survey. Section 4 investigates the effect of organizational structure on both management practices and firm performance. Section 5 discusses results on climate-change related innovation. Section 6 concludes and outlines the future directions for our work.

[2] A recent exception is a study by Martin and Wagner (2009) on the effect of the Climate Change Levy on patent applications by UK firms.

[3] For instance, Jaffe and Stavins (1994) demand that "explanations must advance beyond the tautological assertion that if the observed rate of diffusion is less than the calculated optimal rate, there must be some unobserved adoption costs that would modify our calculations of what is optimal" (p. 805).

2 Data

2.1 Interview design

We conducted structured telephone interviews with 190 managers at randomly selected UK production facilities belonging to the manufacturing sector between January and March of 2009.[4] The interview setup bears close resemblance to the “double-blind” management survey design that was developed by Bloom and van Reenen (2007) in collaboration with a major management consulting company. The survey is conducted over the telephone as a loosely structured dialogue with open questions that are not meant to be answered by “yes” or “no”. On the basis of this dialogue, the interviewer then assesses and ranks the company along various dimensions. A defining characteristic of this research design is that interviewees are not told in advance that they are being assessed, and interviewers do not know performance characteristics of the firm they are interviewing.

The interview format was designed so as to avoid several sources of bias that typically arise in conventional surveys (Bertrand and Mullainathan, 2001). For instance, experimental evidence shows that the respondent’s answers can be manipulated by making simple changes to the ordering of questions, to the way questions are framed, or to the scale on which respondents are supposed to answer. Bias of this kind is attributed to cognitive factors and is minimized here by asking open questions and delegating the task of scoring the answers to the interviewer. To the extent that interviewers are subject to cognitive bias, this can be controlled for using interviewer fixed effects.

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 compounded in situations where respondents do not have a firm attitude towards 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 linked to independent data on economic performance as a validation exercise.

[4] For additional information about the interviews see Appendix A. The complete interview structure is provided in Appendix B.

2.2 Interview practice

Interviewees were selected at random from Bureau Van Dijk's ORBIS database which provides annual accounting data for 55 million companies worldwide.[5] We restricted the sampling frame to all UK firms that had more than 250 but less than 5000 employees in 2007. The focus on medium-sized companies that are not household names is meant to minimize the chance that the interviewer has prior knowledge of the company's performance. Interviews were conducted with the plant manager or other manager with profound knowledge of the production site such as the production manager, chief operating officer, the chief financial officer, and sometimes the environmental manager. Intervieweeswere emailed a letter of information in advance of the interview which alsoassured them their answers were going to be treated as confidential. On average, an interview ran for 42 minutes.

We adopt an ordinal scale of 1 to 5 to measure management practices related to climate change. For each aspect of management ranked in this way (see section 2.3 below for a detailed description) interviewers ask a number of open questions. Questions are ordered such that the interviewer starts with a fairly open question about a topic and then probes for more details in subsequent questions, if necessary. We further provide exemplary responses that guide interviewers as to giving a high versus an intermediate and a low score for the relevant dimension. The goal is to benchmark the scoring of firms according to common criteria. For instance, rather than asking the manager for a subjective assessment of the management's awareness of climate change issues, we gauge this by how formal and far-reaching the discussion of climate change topics is among senior managemers.

In order to check the consistency interviewer scoring many interviews were double-scored by a second team member who listened in.[6] We called 765 manufacturing firms of which 132 refused to participate straight away. In the remaining 443 cases interviewers were asked to call back at another time but did not follow up after the target number of interviews had been achieved. Counting only interviews granted and refused explicitly, we obtain a response rate of 59%.[7]

[5] See http://www.bvdep.com

[6] For a discussion of the results, see Appendix A.2.

[7] This is comparable to the 54% response rate obtained in Bloom and van Reenen (2007).

2.3 Interview scope

The interviews seek to gather information on three main factors concerning the effectiveness of climate change policies. First, we wish to understand the drivers behind a firm's decision to reduce GHG emissions. Second, we want to learn about the specific measures firms adopt both voluntarily and in response to mandatory climate change policies. This includes technology adoption and innovation. Finally, we want to assess the relative effectiveness of various measures.

Table 1: Interview summary statistics

		(1) number of firms responding	(2) mean	(3) standard deviation	(4) number of firms answering "don't know"	(5) number of firms refusing to answer	(6) total number
1	**manager's tenure in post**	189	5.22	5.25	1	0	190
2	**manager's tenure in company**	190	12.20	10.10	0	0	190
3	**awareness of climate change score**	188	3.45	1.08	2	0	190
4	**climate-change related products score**	188	1.77	1.20	2	0	190
5	**stringency of ETS target score**	27	2.85	1.32	6	0	33
6	**ETS target (in percent)**	10	11.50	14.20	22	1	33
7	**rationality of behaviour on ETS market score**	21	2.10	1.34	12	0	33
8	**stringency of CCA target score**	68	3.57	1.01	5	0	73
9	**CCA target (in percent)**	47	13.10	11.80	25	1	73
10	**competitive pressure due to climate change score**	171	2.60	0.95	19	0	190
11	**competitive relocation due to climate change score**	187	1.11	0.42	3	0	190
12	**customer pressure score**	188	2.60	1.25	2	0	190
13	**investor pressure score**	175	2.57	1.40	15	0	190
14	**energy monitoring score**	186	3.49	1.37	4	0	190
15	**energy consumption targets score**	183	2.90	1.40	7	0	190
16	**energy consumption target (in percent)**	109	22.20	17.30	22	1	132
17	**GHG monitoring score**	183	2.14	1.27	7	0	190
18	**GHG emissions targets score**	165	1.56	1.13	25	0	190
19	**GHG emissions target (in percent)**	25	21.70	24.50	12	0	37
20	**target enforcement score**	185	2.52	1.43	5	0	190
21	**measures on site score**	183	3.04	1.08	7	0	190
22	**energy reduction achieved through one recent measure**	96	12.80	13.80	94	0	190
23	**GHG emissions reduction achieved through one recent measure**	42	15.50	18.90	148	0	190
24	**hurdle rate used for investments in energy efficiency improvement score**	1	1	.	189	0	190
25	**payback time used for investments in energy efficiency improvement score**	140	2.11	1.08	48	2	190
26	**barriers to investments in energy efficiency score**	149	2.86	0.63	41	0	190
27	**Research and Development - broad innovation score**	183	3.25	1.19	5	2	190
28	**process innovation score**	181	2.28	1.10	7	2	190
29	**product innovation score**	176	2.06	1.29	11	3	190
30	**purchasing choices score**	178	2.51	1.29	12	0	190
31	**further reductions achievable at current prices**	138	8.82	8.60	52	0	190
32	**further reductions technologically achievable**	128	27.70	20.00	62	0	190
33	**adaptation to climate change score**	174	1.32	0.75	16	0	190

Notes: Summary statistics from interview data with 190 firms

Table 1 provides an overview of managers' responses. It summarizes the mean, standard deviation, maximum and minimum values of each raw score and reporting the number of managers who refused to answer or did not know. Responses ranked on an ordinal scale may not be comparable across questions as in some cases all firms where given scores between 2 and 4 or 1 and 3. To normalize those responses, we computed z-scores by subtracting from the raw score the average score and dividing by the standard deviation. Histograms of the z-scores constructed for each question are presented in Figure 3 in Appendix A. In the remainder of this section we explain selected questions of the interview in more detail and highlight patterns in the raw data which speak to the energy efficiency paradox and to the role of policies and management practices in explaining it.

Awareness. The interview begins with a question about the management's awareness of climate change issues. For a medium score we expect some evidence of a formal discussion, e.g. that this has been on the agenda of a management meeting. A high score is given only if it is evident that the management has studied the implications of climate change in detail and that the findings have been integrated into the strategic business plan. We record if climate change is perceived as having a positive impact. More specifically, we want to know whether climate change could be a business opportunity. We thus ask whether the firm sells climate-change related products and about their importance in revenue.

Government policies. Firms covered by the UK Climate Change Agreements (CCA)[8] and/or the EU Emission Trading Scheme (EU ETS) are asked how stringent these policies are and about their behavior on the permit markets. What is more, we ask about participation in voluntary policies offered by the British government such as the Carbon Trust (CT) energy audits[9] and online tools, the Enhanced Capital Allowance (ECA) scheme,[10] and whether these initiatives were perceived as useful.

The firms in the sample were exposed to a broad range of compulsory and voluntary climate

[8]The CCA is a voluntary agreement that offers participating firms an 80% discount on their tax liability under the Climate Change Levy (CCL) if they promise to reduce their energy consumption. See Martin et al. (2009) for a plant-level analysis of its causal impacts on energy use and economic performance.

[9]Set up by the UK government in 2001 as an independent company, the Carbon Trust helps businesses to cut carbon emissions, to save energy and to commercialize low carbon technologies. Among the various services it offers to firms and to the public sector are free energy audits. An independent consultant identifies energy-saving opportunities and supports their practical implementation. If capital expenditure is necessary, the consultant calculates the payback period. A facility's carbon footprint can also be calculated.

[10]This scheme was introduced by the UK government in 2001 as part of the Climate Change Levy Programme. It grants firms a 100% first-year capital allowance against taxable profits on investments in equipment that meets energy-saving criteria. The list of criteria for each type of technology is maintained by the Carbon Trust. The Trust maintains a second list with the products and technologies that are eligible for the ECA.

policies implemented in the UK over the past decade. Out of the 190 firms, 33 were in the EU ETS, 73 were in a CCA and 27 participated in both schemes. Regarding voluntary policies we find that 131 firms had received an energy audit from the Carbon Trust and 27 firms took advantage of the ECA. Furthermore, 41 firms used online tools provided by the Carbon Trust, 8 received innovation grants from this institution and 10 adopted the Carbon Trust standard.

Competitive pressure. To assess the relative impact of climate change policies on competition at home and abroad, we inquire about the relative standing of a firm compared to domestic competitors and whether regulation has induced the firm to consider relocation to unregulated countries.

Other drivers. We ask about the role of consumers on the one hand and investors on the other hand in driving management decisions relevant to climate change. When told that consumers or investors demand climate friendly products and practice, the interviewer gauges the extent of the pressure by inquiring about the information that they demand in order to be convinced (e.g. a mere label vs. hard data on GHG emissions).

Monitoring and targets. A number of questions relate to the firm's rigor in monitoring its energy use and GHG emissions. Monitoring can range from a glance at the energy bill (lowest score) to detailed monitoring of both energy use and carbon flows embodied in the firms products and intermediate goods. To be given the highest score, a firm needs external verification of those figures. If monitoring is in place, we ask whether management is given specific targets for energy use and for GHG emissions. We inquire about the stringency of such targets and about the incentives provided to achieve them.

Roughly two thirds (125) of the firms in our sample have targets for energy consumption (17 of which are expenditure targets, the others being quantity targets). The percentage reduction in energy consumption to be achieved over the next five years has a mean of 22.2% and a standard deviation of 17.3. For comparison, the average reduction in energy consumption that firms achieved through a single recent measure is 12.8%. The average stringency of these targets is estimated at 2.9 and the average rigor of energy monitoring at 3.49.

Targets on GHG emissions are much less frequent. Only 37 firms have such a target, of which only 11 also include indirect GHG emissions. Emission reduction targets for the next 5 years average at 21.7% with a standard deviation of 24.5. Both target stringency and monitoring scores are lower than in the case of energy consumption targets. Further, the distribution of the energy monitoring score is left-skewed whereas the one for GHG monitoring is right-skewed and bimodal.

GHG emission reducing measures. We inquire about concrete measures taken on site to reduce GHG emissions. We ask the manager to discuss the measure that had the biggest impact in more detail, how the firm learned about the measure and what motivated its adoption. In regards to the debate about the “energy efficiency gap” we are also interested in measures that were considered but eventually not adopted. We ask the manager about the reasons for this decision and record the hurdle rate or payback criterion as well as other factors if they were relevant.

The responses provide new evidence on the energy efficiency paradox. The score capturing the payback criteria for energy efficiency investments averages at 2.11 with a standard deviation of 1.08 (cf. row 25 of Table 1). This corresponds to a payback time of 3 to 5 years. 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%. This appears rather high in view of the fact that the typical energy efficiency investment involves a known technology (e.g. upgrading a boiler, compressed air system or lighting system) and generates a stream of cost savings at a very low risk (DeCanio, 1998). While this finding is consistent with other evidence on the energy efficiency paradox, we cannot reject the hypothesis that firms apply the same payback criteria to energy efficiency projects as to other projects. In fact, two thirds of the 149 respondents told us that the payback criteria for energy efficiency projects and those applied to other cost-cutting projects are equally stringent. Of the remaining firms, some adopt more lenient payback criteria for energy efficiency projects, whereas others discriminate against them.

When asked about the potential for future GHG abatement, managers said that they could cut GHG emissions by another 8.8% on average (median 6.5%), “without compromising on the firm’s economic performance”. In other words, a sizable amount of GHG abatement could be achieved at zero incremental cost. Of the 139 firms that answered this question, only 21 answered that they have exhausted such possibilities (i.e. 0% reduction). This finding speaks directly to the energy efficiency paradox and provides a sense of the magnitude of the inefficiencies to be captured.

Organizational structure. Previous research on energy efficiency points to a possible effect of organization structure on management of climate change issues. We collect information on the title and responsibilities of the highest-ranking manager dealing with climate change and energy issues, his distance from the CEO and any recent change in this position. We discuss this information in detail in Section 4 below.

Innovation. We distinguish between three dimensions of R&D. We first ask questions about the importance of R&D in the firm globally. Next, we inquire about climate-change related projects that specifically aim at reducing GHG emissions in the production process. Finally, we discuss innovation of products that would allow a firm's customers to reduce GHG emissions in their use. For each type of innovation, we record its geographical concentration in the firm, the magnitude and the motivation behind it and ask about possible other environmental benefits from this type of R&D.

Most of the firms in our sample undertake some form of R&D activity. Interestingly, the distribution of the "climate-change related process innovation" score is right-skewed with the majority of firms scoring below the mean. We find that only a minority of firms engage in "climate-change related product innovation". Among those who do, the distribution of this measure is approximately symmetric.

Other measures. We inquire about other ways in which the firm reduces GHG emissions such as clean investment options and voluntary carbon offsetting programs. We also record any measures the firm has taken to adapt to actual or expected impacts of global climate change.

2.4 Summary indices

In regards to exploiting the interview data for multivariate analysis, we construct summary indices in order to aggregate the vast amount of information we gathered and to deal with inevitable collinearity in the responses. A summary index is constructed for each of the overarching themes addressed in the interview. Table 2 provides a graphical representation of the construction of each summary index and explains how these indices are aggregated up to obtain an overall index of climate-friendliness. Each index is constructed as an unweighted average of the underlying z-scores, and the overall index is constructed as an unweighted average of all summary indices.[11] The relevance of each of the components will necessarily differ across sectors. In the regressions below, we include sector dummies (at the 3-digit SIC level) to control for systematic differences

[11] The "barriers" and the hurdle rate z-scores are multiplied by -1 to reflect the fact that a more stringent criterion for investments in energy efficiency translates into a higher score but reduces the "climate friendliness" of the firm.

Table 2: Construction of summary indices

QUESTIONS	sign	index		overall index
awareness of climate change score	+			
Climate-change related products score	+	awareness		**+**
positive impact of climate change	+			
participation in ETS (0/1)	+			
stringency of ETS target score	+			
ETS target (in percent)	+	ETS		**+**
Length of participation	+			
rationality of behaviour on ETS market score	+			
participation in CCA(0/1)	+			
stringency of CCA target score	+	CCA		**+**
CCA target (in percent)	+			
Length of participation	+			
competitive pressure due to climate change score	+	competitive Pressure		**+**
competitive relocation due to climate change score	+			
customer pressure score	+	other drivers		**+**
investor pressure score	+			
energy targets presence (0/1)	+			
energy monitoring score	+			
energy consumption targets score	+	energy quantity targets		**+**
energy consumption target (in percent)	+			
Length of target existence	+			
Target enforcement score	+		Targets	
GHG targets presence (0/1)	+			
GHG monitoring score	+			
GHG emissions targets score	+	GHG targets		**+**
GHG emissions target (in percent)	+			
Length of target existence	+			
Target enforcement score	+			
Carbon Trust energy audit participation (0/1)	+	CT Audit		**+**
Carbon Trust energy audit (how long ago)	+			
Enhanced Capital Allowance scheme participation (0/1)	+	Enhanced Capital Allowance		**+**
Enhanced Capital Allowance scheme (how long ago)	+			
Research and Development - broad innovation score	+			
process innovation score	+	innovation		**+**
product innovation score	+			
measures on site score				**+**
hurdle rate for energy efficiency investments score				**-**
payback time for energy eff. investments score				**+**
barriers to investments in energy efficiency score				**-**

Notes: Indices are constructed as averages of the z-scores for the answers with weights 1 or -1.
The awareness index includes both the awareness z-score, a dummy for whether or not the manager mentioned a positive impact of climate change and the climate-change related products z-score. The ETS and CCA indices are constructed as the average of the normalized target, length of participation, participation and the z-scores for regulatory stringency. Rationality of market behavior is also included for the ETS. The competitive pressure index combines the competitive pressure and relocation z-scores, while the "other drivers" index averages the z-scores for customer and investor pressures.
We devise two separate indices for targets pertaining to energy use and GHG emissions. Both are constructed as the mean of the respective z-scores for the presence of a target existence, percentage reduction, the stringency, the time it has been in place, as well as monitoring and enforcement. We also compute a comprehensive targets index as the simple mean of both indices.
The Carbon Trust energy audit and the ECA are voluntary policies. The corresponding indices are based on a binary measure of participation and the number of years that have passed since the firm participated. Finally, we compute an innovation index as the mean of the z-scores for product innovation, process innovation and general R&D intensity. Table displays descriptive statistics for all indices along with those for the productivity variables contained in the ORBIS database.

The Overall Index of Climate-Friendliness is computed as the unweighted average of sub-indices.

Table 3: Descriptive statistics of ORBIS matched dataset

	(1) number of firms	(2) mean	(3) standard deviation	(4) p10	(5) p25	(6) p75	(7) p90
ORBIS variables							
turnover (ln)	183	11.600	1.23	10.30	10.80	12.30	13.30
employment (ln)	184	6.190	0.97	5.27	5.59	6.77	7.51
capital (ln(fixed assets))	188	10.400	1.52	8.52	9.48	11.40	12.40
materials (ln(cost of goods - wage bill))	153	10.800	1.33	9.31	9.91	11.60	12.60
Survey indices							
overall climate friendliness index	190	-0.110	0.41	-0.65	-0.43	0.16	0.43
awareness index	190	0.014	0.69	-0.74	-0.43	0.18	1.04
ETS index	175	-0.310	0.58	-0.54	-0.54	-0.54	0.55
CCA index	172	-0.340	0.73	-0.93	-0.93	0.36	0.80
competitive pressure index	189	0.022	0.85	-1.03	-0.47	0.09	0.81
other drivers index	189	0.032	0.85	-1.19	-0.78	0.70	1.10
energy targets index	190	-0.130	0.76	-1.28	-0.91	0.48	0.69
GHG targets index	189	-0.091	0.67	-0.78	-0.77	0.34	0.94
Carbon Trust energy audit index	181	-0.250	1.01	-1.73	-1.73	0.47	0.73
Enhanced Capital Allowance index	166	-0.160	0.76	-0.48	-0.48	-0.48	0.90
innovation index	184	-0.008	0.77	-1.03	-0.46	0.62	1.09

Notes: Summary statistics for the 190 firms from the survey. The first four variables are obtained from the Orbis dataset of Bureau Van Dijck. The survey indices are constructed as averages of the z-scores for various answers with weights 1 or -1, as detailed in Table 4. The overall index of climate-friendliness is computed as the unweighted average of sub-indices.

across sectors. That is, we compare the effects of climate friendliness on outcomes within an industry rather than across industries. Table 3 reports descriptive statistics for both the summary indices and the main performance variables in the ORBIS dataset.

Table 4: Firm characteristics

		(1) mean	(2) standard deviation	(3) median	(4) top 10th percentile average	(5) lowest 10th percentile average	(6) number of firms
1	**global number of employees**	17,306	47,760	2,500	116,594	141	153
2	**UK number of employees**	1,324	3,880	400	7,440	107	176
3	**plant size**	362	342	280	1,028	66	183
4	**firm number of employees in 2005 ***	784	873	436	2,936	122	172
5	**number of sites globally**	68	294	7	494	1	161
6	**number of sites in UK**	5	9	2	24	1	185
7	**turnover (million USD - 2005) ***	238	341	110	1,105	21	172
8	**Earnings before Interests and Taxes (EBIT) (thousand USD - 2005) ***	5,226	37,384	2,534	61,948	-24,570	175
9	**age of company ***	33	29	22	92	3	190
10	**age of company in UK**	68	54	50	183	9	178
11	**number of competitors globally**	39	149	6	311	1	140
12	**number of competitors in the UK**	11	37	4	71	0	171
13	**proportion of production exported**	36	34	30	86	0	169
14	**proportion of inputs imported**	42	33	40	98	0	151
15	**number of shareholders ***	5	13	2	37	1	190
16	**number of subsidiaries ***	4	5	2	16	0	190
17	**proportion of managers**	11	8	10	27	2	170
18	**proportion of employees with a university college degree**	15	15	10	47	1	146
19	**proportion of employees that are unionised**	34	35	25	93	0	158
20	**turnover of firm's global ultimate owner (million USD) ***	9,561	20,716	3,270	51,800	43	112
21	**firm's global ultimate owner number of employees (last available year) ***	27,464	52,884	10,709	147,489	188	106
22	**fraction of running costs for energy**	13.90	15.80	9.00	45	1	80
23	**fraction of turnover for energy**	6.10	9.00	2.00	24	0	13
24	**site carbon pollution (tons of CO_2)**	154,664	717,146	13,905	400,000	545	52

Notes: Some variables have a missing value in the sample of the 190 interviewed firms. A star(*) denotes data available for some firms in Orbis. Non starred data is obtained through interviews.

2.5 Firm characteristics

The 190 interviewed firms are from different subsectors of the manufacturing sector (such as paper mills, ship repair, semiconductors, etc.). Table 4 summarizes their main characteristics based on both the ORBIS data and on interview responses to part IX of the questionnaire in Appendix B. Firm size in terms of UK employees ranges between 20 and more than 45,000,[12] while global and plant size also show a strong disparity. Seventy percent are multiunit firms, while 80% of firms are ultimately owned by foreign multinationals of different origins such as South Africa, Korea, France or the US. Net income and turnover, as reported in their annual accounts, show as much variation. Firms also differ greatly in their age, with some very young firms (one year old) and one more than two centuries. The degree of competition faced by firms both in the UK and internationally ranges from non-existence to very high levels. Most firms export their products and import a share of their inputs, though again the magnitudes vary widely. Union membership varies between none and all employees, and the proportion of managers in the firm is usually below fifteen percent. Firms in the sample therefore represent a wide variety of activities, size, profitability, age, international activity and ownership.The share of energy costs in total costs was reported by half the interviewees and ranged from 0 to 80%, while some reported energy cost as a proportion of turnover which ranged from 0% to 32%. Total carbon emissions exhibit large disparities across the 54 firms that reported them, ranging from less than a ton to over 400,000 tons. Of the production sites we interviewed, 68% had implemented an ISO14000 environmental management system.

Importantly, interviewed firms are not significantly different from non-interviewed firms in regards to the observable characteristics used in our analysis. This is shown in Panel A of Table 5 where each of the principal firm characteristics available from the ORBIS database (turnover, employment, materials, and capital) is regressed on an dummy variable indicating that a firm was contacted and a full set of sector and year dummies, with the result that the estimated coefficients are small and statistically insignificant. For the set of firms that either conceded or refused an interview, we ran analogous regressions to estimate an intercept specific to firms that granted us an interview. The results in Panel B of Table 5 show that none of these intercepts is statistically significant. We thus conclude that our sample is representative of the underlying population of medium-sized manufacturing firms in the UK.

[12] Although we had limited the sampling frame for contact information to firms below 5000 employees, these were in several cases sub-units of much larger companies.

Table 5: Representativeness of interviewed firms

	(1) **turnover**	(2) **employment**	(3) **capital**	(4) **materials**
A. All firms				
firm contacted	0.03	0.04	0.07	0.11
	(0.44)	(0.7)	(0.73)	(1.29)
number of firms	6393	7359	7308	5869
R-squared	0.56	0.56	0.65	0.65
B. Contacted firms				
firm granted interview	0.11	0.11	0.30	0.04
	(0.62)	(0.91)	(1.46)	(0.18)
number of firms	295	316	315	273
R-squared	0.56	0.56	0.65	0.65

Notes: Regressions in panel I are based on the entire set of medium-sized firms contained in ORBIS. Each column shows the results from a regression of the ORBIS variable given in the column head on a dummy variable indicating whether a firm was contacted or not. Panel II shows analogous regressions for the set of contacted companies and with an indicator for whether an interview was granted. All regressions are by OLS and include year dummies and 3-digit sector dummies. Standard errors are clustered at the firm level and are robust to heteroskedasticity and autocorrelation of unknown form.* significant at 10%; ** significant at 5%; *** significant at 1%.

2.6 Matching interview data to the UK production census

A distinctive feature of our research design is the effort to link the interview data with independent performance data, both as a means of validation and to examine actual impacts. ORBIS data allow us to derive measures of productivity and examine how they relate to various management survey variables. We also match the firms in our sample to observations in the Annual Respondents Database (ARD), the most comprehensive and detailed business dataset for the UK. Data access is restricted to approved researchers working on the premises of the ONS. The ARD contains data on energy expenditures that are of particular interest in this context. Combining look-up tables provided by the ONS for the ORBIS and ARD datasets and information on the facilities postcode we obtain 130 (68.4%) unique matches for the firms we interviewed.

Table 6 presents descriptive statistics for the ARD variables in the sample of matched firms. All variables are expressed in natural logarithms. We consider two alternative measures of energy intensity. The first one, energy expenditures divided by variable costs, is a cost-based measure that is insensitive to firm-specific markups. The second one is calculated as energy expenditures divided by gross output. If firms adjust their price-cost markup in response to a change in the factor input mix, the two measures may not always give the same picture. However, the distributional characteristics of both measures are very similar and they are highly correlated. Column 2 of

Panel A exhibits a considerable amount of dispersion in energy intensity between firms in our sample. After controling for 3-digit industry codes in Panel B, the standard deviation falls by only one third. That is, most of the variation in energy intensity is driven by differences between firms rather than industries. As the next section will show, differences in management practices go a long way to explain this variation.

Table 6: Summary statistics ARD variables pooled sample

	(1) mean	(2) standard deviation	(3) N	(4) median	(5) mean, bottom 10 %	(6) mean, bottom 25 %	(7) mean, top 25 %	(8) mean, top 10 %
A. Variables								
energy expenditure over gross output	-4.102	1.003	678	-4.087	-5.837	-5.313	-2.840	-2.139
energy expenditure over variable costs	-3.989	0.961	680	-3.997	-5.679	-5.177	-2.766	-2.148
gross output	10.726	1.243	683	10.781	8.496	9.257	12.171	12.799
material	10.228	1.226	682	10.197	8.143	8.734	11.810	12.401
energy expenditure	6.643	1.457	680	6.495	4.243	4.896	8.559	9.415
employment	6.090	0.931	683	6.004	4.589	5.098	7.231	7.745
capital	10.429	1.215	495	10.395	8.428	8.993	11.962	12.492
B. Within sector variation								
energy expenditure over gross output		0.674	678	0.018	-1.274	-0.808	0.778	1.172
energy expenditure over variable costs		0.646	680	-0.008	-1.217	-0.756	0.777	1.168
gross output		0.844	683	0.000	-1.595	-0.974	0.977	1.535
material		0.832	682	0.000	-1.528	-0.995	1.025	1.563
energy expenditure		0.859	680	0.015	-1.714	-1.053	1.011	1.545
employment		0.554	683	0.020	-1.014	-0.696	0.677	1.036
capital		0.745	495	0.010	-1.447	-0.951	0.904	1.353

Notes: Descriptive statistics for the ARD variables over the pooled sample, from year 2000 to 2006. All variables are in logs. Panel B summarizes the residuals from regressions on industry dummies at the SIC 3-digit level.

3 Management practices and firm performance

3.1 Concepts

We are interested in two closely related measures of firm performance, namely energy efficiency and TFP. In theory, ‘good management’ increases both measures. It can mitigate managerial slack and discourage wasteful practices, thus raising output for a fixed amount of factor inputs. It might also change production in a way that increases output by more than the necessary increment in factor inputs. 'Good management' is a rather general term that could be interpreted to embrace both management practices and organizational structure. Since we wish to distinguish between these two aspects, we formulate the working hypothesis that a firm's organizational structure determines its energy efficiency *through* its ability to adopt effective management practices and adequate responses to public policy. That is, the "structural model" we have in mind consists of (i) a mapping from organizational structures into management practices and (ii) a mapping from management practices into firm outcomes. This section provides empirical evidence on the latter mapping. The former mapping will be the subject of Section 4 below.

3.2 Management practices and productivity

We use productivity data from the ORBIS database (summarized in Table 3) to estimate the relationship between management practices and productivity.[13] Each cell in Table 7 corresponds to a different regression of the logarithm of turnover on a single management variable and various control variables. The cell contains the coefficient estimate and standard error for the management variable indicated in the row header, given the specification of the respective column. The regressions in the first column includes the logarithm of employment as a control so that the coefficient on the management variable can be interpreted as the effect on labor productivity. Regressions in the second column of Table 7 include employment, materials and capital (all in logarithms) as additional controls.[14] This is a straightforward way of estimating the correlation between TFP and the management variable of interest. All regressions include 3-digit sector dummies, firm age (linear and quadratic terms) and year effects. To control for interviewer noise, we also include a full set of interviewer dummies and a dummy variable for experience indicating whether the interviewer had conducted less than 10 interviews. As respondent's characteristics we include a dummy variable indicating a technical background as well as the interviewer's assessments of the respondent's knowledge of the firm and of the respondent's concern about climate change (cf. questions X.2 and X.3 of the questionnaire in Appendix B).

The principal result in Table 7 is the strong positive association between the climate friendli-

[13]As was explained above, by construction we get the largest possible sample using the ORBIS data.
[14]The number of firms drops from 182 to 153 because some firms did not report data on capital and materials.

Table 7: Regression results using ORBIS data

	(1)	(2)
Summary indices	**Labour productivity**	**TFP**
overall index	0.354***	0.119**
	(0.111)	(0.054)
awareness	0.02	0.047**
	(0.044)	(0.022)
competitive pressure	-0.05	0.01
	(0.040)	(0.030)
other drivers	0.06	0.00
	(0.043)	(0.023)
innovation	0.07	0.00
	(0.050)	(0.026)
energy targets	0.225***	0.075***
	(0.050)	(0.027)
GHG targets	0.237***	0.05
	(0.064)	(0.034)
Carbon Trust audit	0.110**	0.03
	(0.048)	(0.028)
Enhanced capital allowance	0.10	0.051*
	(0.064)	(0.031)
ETS	0.12	0.06
	(0.077)	(0.051)
CCA	0.259***	0.04
	(0.065)	(0.036)
barriers to invest in	-0.099**	-0.075**
energy efficient projects	(0.047)	(0.029)
payback time	0.00	0.01
	(0.053)	(0.029)
Observations	1387	1106
Firms	182	153
R-squared	0.865	0.952

Notes: Each panel represents a different regression of a CEP Climate Change Management Survey Score and various control variables. The dependent variable in all regressions is the logarithm of turnover. In the first column, the logarithm of employment is included in the explanatory variables such as to capture labour productivity, while the second column approximates total factor productivity by including also the logarithm of capital and materials. Each panel reports the coefficient and standard errors clustered at the firm level (i.e. robust to heteroskedasticity and autocorrelation of unknown form) relative to each explanatory overall index or score included in separate regressions. The number of observations, firms and R-squared vary for each regression; the numbers reported are those of the regression on the overall index.All regressions include firm age (linear and quadratic), 3-digit sector dummies, year dummies, interviewer noise controls (dummies for interviewer identity and for experience less than 10 interviews), and respondent characteristics (dummy for technical background, post-interview scores for knowledge about the firm and concern about climate change issues). * significant at 10%; ** significant at 5%; *** significant at 1%.

ness index derived from the interview responses and productivity. This correlation is statistically significant for both productivity measures, but the coefficient is smaller when controlling for capital and materials (0.174 instead of 0.326). Among other things, climate friendliness might affect productivity by increasing investment in capital through cleaner technologies. In this case the coefficient in column 2 falls short of capturing the full effect on productivity since it is conditional on capital.

The finding for climate friendliness is in line with previous work showing that firms with better management practices are, on average, more productive (Bloom and van Reenen, 2007) and more energy efficient (Bloom et al., 2009).[15] In addition, the present study sheds light on the question of which management practices are driving this result. For example, we find that climate change awareness is positively correlated with TFP. Hence more productive firms are also more likely to have climate-change related products, to expect positive impacts of climate change or to exhibit more awareness of climate change issues among its management.

We also find a rather strong, positive relationship between productivity and the energy targets index measuring the monitoring of energy use, the presence and stringency of targets as well as their enforcement. Improving the overall index of energy targets from the 25th to 75th percentile (1.39 in Table 3) can be associated with an 11% improvement in TFP.[16] This finding is striking, as it supports the view that the simple practice of setting targets for energy use and following up on them can have a discernible effect on a firm's productivity.

We obtain a negative coefficient on the score measuring barriers to invest in energy efficient projects (cf. question V.8.3. in Appendix B). This implies that firms that discriminate against investments in energy efficiency are also less productive on average. Notice that there is no statistically significant correlation between productivity and the payback time criterion as such.

The positive and significant coefficient on GHG targets, like the ones for the Carbon Trust audit and CCA indices, becomes insignificant once we include capital. Given the complementarity between energy and capital, capital might act as a proxy for energy use in these regressions and hence control for possible self-selection of energy-intensive firms into these schemes. We also find that TFP is positively associated with the ECA index at 10% significance. While this result

[15] Related to this, Shadbegian and Gray (2003, 2006) find a positive correlation between production efficiency and pollution abatement efficiency in the US paper and steel industries, even after controlling for observable factors.

[16] $\exp(1.39 \cdot 0.075) - 1 = 11\%$

is reassuring, the ECA and other climate policies were not implemented with the primary goal of enhancing productivity of the business sector but to promote energy efficiency, to which we shall turn in the next section.

3.3 Management practices and energy efficiency

As a first approximation to the relationship between management practices, climate change policies and energy efficiency, we regress different measures of energy intensity on a single management index or score and on a vector of control variables. The goal behind these regressions is to uncover the unconditional patterns of correlation between management, policy and energy variables after correcting only for sector, time, and size effects. In Table 8, we report the results in a similar way as in Table 7 but now having as dependent variable (the logarithm of) energy intensity, defined either as energy expenditure divided by gross output (in columns 1 to 3) or as energy expenditure over non-capital expenditure (wages and materials expenditure, in columns 4 to 6).

To begin, the index of overall climate friendliness is negatively associated with energy intensity. This result is robust across specifications once the 3-digit level sector dummies are included, and it is consistent with the productivity results reported in the previous section. To get a sense of the magnitude of this effect, we calculate by how much a firm's energy intensity changes, ceteris paribus, when shifting its overall climate friendliness from the 25th percentile to the 75th percentile of the distribution. We do so by taking the interquartile range from the fifth row of Table 3 and multiplying it by the coefficient in column two of Table 8, which yields $(0.16+0.43)\cdot(-0.51) = -0.30$. In absolute terms, this number corresponds to almost half of the standard deviation in energy intensity within sectors and accounts for almost one fifth of the interquartile range (cf. Panel B of Table 6). From this we conclude that the relationship found between climate friendly management practices and energy intensity is economically significant.

We further examine this relationship using more specific measures of climate friendliness. The indices for competitive pressure and other drivers (consumer and investor pressure) are both negatively and significantly associated with energy intensity, the former index at 10% and the latter at 5% significance. This suggests that firms cope with increasing pressure on both product and capital markets by enhancing their energy efficiency. The coefficient on innovation is negative, too, though not statistically significant.

Firms with higher values on the energy consumption targets index are on average less energy intensive when controlling for sector. This result is statistically significant at 10% or better in most cases. In contrast, the coefficients on the index for GHG emission targets are positive and significant when both sector and size controls are included.

Table 8: Regressions of energy intensity on management variables

	(1)	(2)	(3)	(4)	(5)	(6)
	energy expenditures over gross output ln(EE/GO)			energy expenditures over variable cost ln(EE/VCOST)		
Summary indices						
overall index	0.009	-0.510**	-0.461*	-0.109	-0.487**	-0.446**
	(0.219)	(0.231)	(0.236)	(0.215)	(0.208)	(0.209)
awareness	-0.232**	-0.187	-0.153	-0.300***	-0.234**	-0.206*
	(0.102)	(0.118)	(0.127)	(0.101)	(0.116)	(0.122)
competitive pressure	-0.263***	-0.130*	-0.136*	-0.275***	-0.151*	-0.156**
	(0.093)	(0.074)	(0.070)	(0.089)	(0.080)	(0.076)
other drivers	0.017	-0.247**	-0.241**	-0.070	-0.279***	-0.273***
	(0.117)	(0.111)	(0.110)	(0.113)	(0.105)	(0.102)
innovation	-0.142	-0.221	-0.133	-0.220*	-0.232	-0.147
	(0.122)	(0.157)	(0.167)	(0.116)	(0.157)	(0.166)
energy targets	0.025	-0.313**	-0.285*	0.050	-0.218*	-0.194
	(0.108)	(0.148)	(0.148)	(0.104)	(0.129)	(0.130)
GHG targets	0.056	0.113	0.206*	0.077	0.167	0.252**
	(0.109)	(0.108)	(0.124)	(0.107)	(0.110)	(0.125)
Carbon Trust energy audit	0.078	-0.074	-0.079	0.065	-0.084	-0.089
	(0.099)	(0.081)	(0.081)	(0.098)	(0.075)	(0.074)
Enhanced Capital Allowance	-0.125	-0.223*	-0.235*	-0.166	-0.191	-0.199*
	(0.123)	(0.127)	(0.126)	(0.116)	(0.121)	(0.120)
ETS	0.259*	0.115	0.205	0.230	0.051	0.123
	(0.140)	(0.160)	(0.159)	(0.139)	(0.149)	(0.146)
CCA	0.428***	0.157	0.167	0.407***	0.227	0.235
	(0.131)	(0.187)	(0.184)	(0.120)	(0.178)	(0.175)
barriers to invest in	0.338***	0.398***	0.387***	0.381***	0.465***	0.460***
energy efficient projects	(0.073)	(0.085)	(0.085)	(0.077)	(0.094)	(0.093)
payback time	-0.010	-0.026	-0.036	-0.035	-0.042	-0.047
	(0.088)	(0.080)	(0.083)	(0.077)	(0.079)	(0.083)
Controlling for						
size (log employment)	no	no	yes	no	no	yes
3 digit sector dummies	no	yes	yes	no	yes	yes
observations	678	678	678	680	680	680
firms	128	128	128	128	128	128

Notes: Each panel represents a different regression of a CEP Climate Change Management Survey Score and various control variables. Each panel reports the coefficient and standard errors clustered at the firm level (i.e. robust to heteroskedasticity and autocorrelation of unknown form) relative to each explanatory overall index or score included in separate regressions. All regressions include firm age (linear and quadratic), year dummies, interviewer noise controls (dummies for interviewer identity and for experience less than 10 interviews), and respondent characteristics (dummy for technical background, post-interview scores for knowledge about the firm and concern about climate change issues). The number of observations, firms varies for each regression; the numbers reported are those of the regression on the overall index. * significant at 10%; ** significant at 5%; *** significant at 1%.

The indices for the two voluntary climate policies (CT energy audit and ECA) are negatively associated with energy intensity when sector dummies are included, but only the ECA index is statistically significant at 10%, another finding consistent with the TFP regression.[17] In contrast,

[17]Causality could run either way to generate this correlation. On the one hand, since the ECA is a government subsidy for investments in energy saving equipment, the policy could be effective at improving energy-efficiency at

the coefficients on the EU ETS and CCA indices are positive. This can be explained by the fact that both policies target energy intensive firms in the first place, and the loss of significance once sector dummies are included speaks to the presence of a selection effect.

The last two rows of Table 8 report the coefficients on two management scores relevant for the debate about the energy efficiency paradox. We find a positive and highly significant association between the barriers to invest in energy efficiency score and energy intensity. This means that, on average, energy intensity is higher in firms that apply more stringent payback criteria to energy efficiency projects than to other projects. Additionally, firms granting longer payback times are less energy intensive, although this finding is not statistically significant. These results are in line with those obtained previously in the productivity regressions.

Table 9 shows that most of these results hold up when regressing energy intensity on all summary indices.[18] The main difference is that the coefficients on the competitive pressure and ECA indices lose significance whereas the results for targets on energy consumption and GHG targets gain statistical significance. Notably, we now find a robust negative relationship between energy intensity and the energy targets index and a positive one for the GHG emission targets index. When interpreted in a causal fashion, the former result tells us that, ceteris paribus, energy targets decrease energy intensity but the latter gives rise to the startling conclusion that GHG targets *increase* energy intensity. One explanation for this would be that firms must switch to more expensive fuels (e.g. from coal to gas) in order to reduce GHG emissions.[19] The coefficient could be biased if we fail to control for an important determinant of the adoption of GHG targets which is also correlated with energy intensity. It seems most plausible, however, that the issue is one of reverse causality. Even if identical GHG emission targets were randomly assigned to some firms and not to others (i.e. in the absence of selection) energy intensive firms are more likely to report

participating firms. Possible transmission channels could involve factors external to the firm, such as binding credit constraints for projects that are not central to the running of their business. The ECA might help firms to relax these constraints and thus increase investments in energy efficiency improvements. On the other hand, it is possible that firms that are more conscious about curbing energy consumption are both more energy efficient and more likely to participate in policies pertaining to these goals.

[18]Due to missing observations for the policy indices (ECA, Carbon Trust audit, EU ETS and CCA), the number of firms drops to 93 when running this regression. In order to avoid sample selection bias we substitute a constant for missing values of these four indices and include dummy variables that take a value of 1 whenever a substitution is made. This procedure allows us to keep 123 firms in the sample while using the full sample to identify coefficients with non-missing observations. Nonetheless, running the regression in the smaller sample of 93 firms gives qualitatively very similar results that are available from the authors upon request.

[19]Recall that the numerator of both intensity measures is energy *expenditures.*

that the target is stringent. Hence a firm's energy intensity determines its value for the GHG index (via the stringency score) and not vice versa. This explains why, all else being equal, firms with a higher GHG targets index are more energy intensive on average.

Table 9: Multivariate regressions of energy intensity on management indices

	(1)	(2)	(3)	(4)	(5)	(6)
	energy expenditures over gross output			**energy expenditures over variable cost**		
Summary indices	ln(EE/GO)			ln(EE/VCOST)		
awareness	-0.211*	0.023	0.065	-0.250**	-0.065	-0.028
	(0.112)	(0.130)	(0.119)	(0.115)	(0.132)	(0.123)
competitive pressure	-0.155*	-0.042	-0.052	-0.191**	-0.102	-0.111
	(0.087)	(0.080)	(0.071)	(0.084)	(0.084)	(0.075)
other drivers	0.095	-0.255**	-0.301**	0.010	-0.287***	-0.328***
	(0.122)	(0.111)	(0.116)	(0.112)	(0.100)	(0.102)
innovation	-0.022	-0.265	-0.138	-0.099	-0.265	-0.153
	(0.109)	(0.186)	(0.160)	(0.103)	(0.181)	(0.162)
energy targets	-0.283*	-0.596***	-0.572***	-0.170	-0.441***	-0.419**
	(0.161)	(0.167)	(0.155)	(0.150)	(0.161)	(0.161)
GHG targets	0.129	0.451**	0.479**	0.168	0.458**	0.483***
	(0.173)	(0.196)	(0.183)	(0.163)	(0.180)	(0.168)
Carbon Trust energy audit	0.036	-0.075	-0.066	0.018	-0.113	-0.106
	(0.094)	(0.072)	(0.069)	(0.089)	(0.076)	(0.072)
Enhanced Capital Allowance	-0.079	0.103	0.112	0.005	0.129	0.137
	(0.265)	(0.237)	(0.189)	(0.277)	(0.228)	(0.189)
ETS	0.129	0.150	0.264*	0.086	0.018	0.119
	(0.143)	(0.171)	(0.149)	(0.142)	(0.157)	(0.141)
CCA	0.540***	0.293	0.248	0.458***	0.337	0.297
	(0.182)	(0.200)	(0.189)	(0.164)	(0.207)	(0.202)
Controlling for						
3-digit sector dummy	no	yes	yes	no	yes	yes
size (log employment)	no	no	yes	no	no	yes
observations	658	658	658	660	660	660
firms	123	123	123	123	123	123
R-squared	0.294	0.671	0.697	0.370	0.721	0.743

Notes: Each column shows the results of a multivariate OLS regression of energy intensity on management indices and other control variables. Twenty of the 123 firms have missing observations for one or several of the policy indices ETS, CCA, Carbon Trust energy audit and ECA. Rather than dropping those observations, we replace the missing values of each of these four indices by a constants and include a dummy variable for each index that takes a value of 1 whenever a substitution is made. This procedure allows us to use the full sample of 123 firms to identify the coefficients on variables without missing observations. All regressions include firm age (linear and quadratic), year dummies, interviewer noise controls (dummies for interviewer identity and for experience less than 10 interviews), and respondent characteristics (dummy for technical background, post-interview scores for knowledge about the firm and concern about climate change issues). Standard errors given in parenthesis are clustered at the firm level and robust to heteroskedasticity and autocorrelation of unknown form. For the "no missing" variables, we have replaced the missing observations (don't know, not asked, refused to respond) by zero, and the "missing id" variables are equal to one if we have replaced a missing value for the corresponding variable and zero otherwise. *** p<0.01, ** p<0.05, * p<0.1

Next we take a closer look at the principal constituents of the indices we found to be significant. In Table 10 we regress energy intensity on the main variables underlying an index, while controlling for all other indices. Panel A shows the decomposition of the "other drivers" index. While both customer and investor pressure exhibit a negative correlation with energy intensity, the coefficient on the latter is more precisely estimated (the large standard errors hint at a multicollinearity problem). Panel B shows that the components of the energy targets index which matter for energy intensity are energy monitoring and the presence of a target rather than its enforcement or its stringency.[20] The results in Panel C corroborate our conjecture that the correlation between energy intensity and the GHG index is driven by the stringency score. We find that the firms with the most stringent GHG emission targets are also the most energy intensive ones.[21] The positive coefficient on GHG monitoring is significant at 10% at best. Finally, Panel D shows that the earlier result for the investment criteria stringency variables are robust in the multivariate regression. The barriers to investments in energy efficiency score continues to be positively and significantly associated with energy intensity whereas the scores for payback time and measures taken on site are negatively associated with energy intensity and less significant.

In sum, the results presented in this section strongly support the view that differences in energy efficiency across firms within a given sector are driven by measurable differences in management practices rather than by various climate policies that have been implemented in the UK. Therefore, for a better understanding of what is driving the energy efficiency paradox, we need to know what determines the adoption of certain climate friendly management practices at the firm level. This is the goal of the next section.

4 Does organizational structure explain management practices?

4.1 Characterizing organizational structure

Previous research has put forth the idea that organizational structure affects a firm's ability to improve its energy efficiency. For instance, in theoretical models by DeCanio and Watkins (1998a) and DeCanio et al. (2000), the firm is represented as a network of agents and the cost of communication between agents depends on the number of nodes between them. When information about novel ways of enhancing efficiency arrives at one end of the network, this does not translate into better performance until the information has been transmitted to all other agents in the network. Using numerical simulations for different networks, DeCanio et al. show that the optimal organizational structure is subject to a trade-off between connectedness and communation cost.

The subsequent analysis tests a stripped-down version of this idea using a representation of

[20]We experimented with including the energy target stringency score in this regression both with the energy targets dummy and without it. In neither case is this variable statistically significant.

[21]When including a dummy for target existence in the regressions – by itself or along with the stringency score – the coefficients are not statistically signficiant when controlling for sector dummies and firm size. The results are available from the authors upon request.

Table 10: Multivariate regressions of energy intensity on selected survey scores and indices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	energy expenditures over gross output			**energy expenditures over variable cost**			**firms/ obs.**
	ln(EE/GO)			ln(EE/VCOST)			
Panel A: other drivers							
customer pressure score	0.147*	-0.211	-0.208	0.097	-0.168	-0.165	107
	(0.086)	(0.134)	(0.130)	(0.078)	(0.122)	(0.119)	582
investor pressure score	-0.162	-0.089	-0.107	-0.226**	-0.178*	-0.195**	
	(0.102)	(0.099)	(0.102)	(0.088)	(0.091)	(0.092)	
R-squared	0.280	0.659	0.670	0.370	0.708	0.720	
Panel B: energy targets							
energy monitoring score	0.029	-0.370**	-0.323**	0.063	-0.252*	-0.199	112
	(0.108)	(0.142)	(0.135)	(0.104)	(0.139)	(0.125)	610
energy targets dummy	-0.163	-0.268**	-0.233**	-0.128	-0.210**	-0.171*	
	(0.105)	(0.104)	(0.105)	(0.100)	(0.091)	(0.092)	
target enforcement score	0.013	0.099	0.049	0.027	0.142	0.087	
	(0.161)	(0.111)	(0.106)	(0.159)	(0.098)	(0.088)	
R-squared	0.290	0.684	0.693	0.366	0.735	0.746	
Panel C: GHG targets							
GHG monitoring	0.123	0.065	0.128	0.160*	0.096	0.164*	113
	(0.095)	(0.106)	(0.098)	(0.087)	(0.100)	(0.092)	616
GHG target stringency	-0.064	0.232***	0.197**	-0.055	0.216**	0.179**	
	(0.072)	(0.086)	(0.084)	(0.071)	(0.083)	(0.081)	
R-squared	0.295	0.669	0.680	0.369	0.714	0.729	
Panel D: energy efficiency measures							
measures on site score	-0.013	-0.151	-0.197**	0.103	0.021	-0.019	80
	(0.151)	(0.100)	(0.089)	(0.121)	(0.095)	(0.083)	440
payback time	0.064	-0.052	-0.096	0.011	-0.134**	-0.173***	
	(0.094)	(0.078)	(0.070)	(0.068)	(0.061)	(0.054)	
barriers to invest in energy	0.347***	0.385***	0.346***	0.410***	0.525***	0.492***	
efficiency projects	(0.102)	(0.091)	(0.081)	(0.078)	(0.074)	(0.067)	
R-squared	0.345	0.775	0.787	0.485	0.834	0.845	
3-digit sector dummies	no	yes	yes	no	yes	yes	
size (log employment)	no	no	yes	no	no	yes	

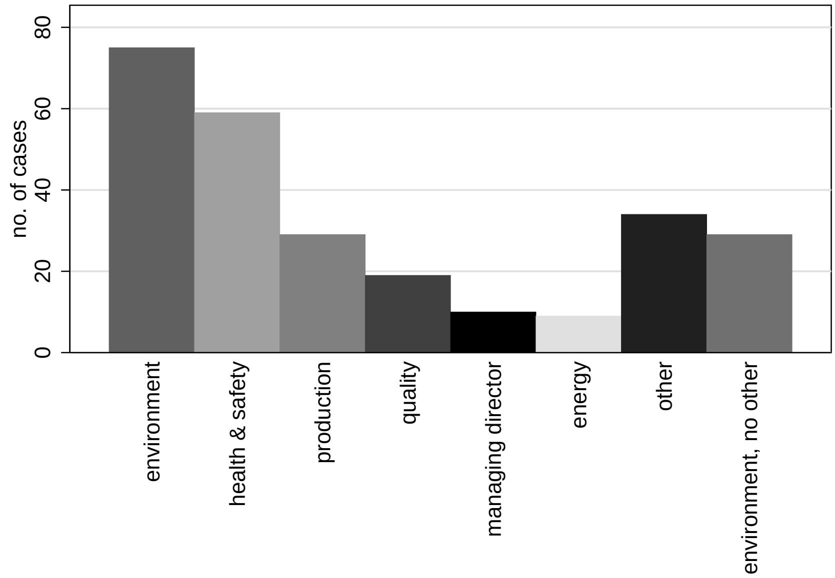
Notes: Each column shows the results of a multivariate OLS regression of energy intensity on normalized interview scores, summary indices and other control variables. Each panel represents a different specification and includes all summary indices other than the index that includes the interview scores included already in the regression. All regressions include firm age (linear and quadratic), year dummies, interviewer noise controls (dummies for interviewer identity and for experience less than 10 interviews), and respondent characteristics (dummy for technical background, post-interview scores for knowledge about the firm and concern about climate change issues). Standard errors given in parenthesis are clustered at the firm level and robust to heteroskedasticity and autocorrelation of unknown form. *** p<0.01, ** p<0.05, * p<0.1

organziational structure which is tractable for regression analysis. Specifically, we use information on the official function(s) of the manager in charge of climate change issues, henceforth referred to as the climate change manager (CCM)[22] as well as information on how far below the CEO this person ranks in the firm's hierarchy. The role of the CCM is likely to affect management practices and performance since different managers have different ways of dealing with climate change issues and regulation. For example, a financial manager is more likely to regard tradable pollution permits as a financial asset whereas a production manager might focus more on complying with the cap implicit in the number of permits allocated to the firm. This is not just because these managers have different professional backgrounds and experiences, but it also reflects the limits of the competences that come with their positions. In our example, the financial manager may lack the authority to instruct the production manager to adjust pollution abatement in response to price fluctuations on the permit market. In turn, the production manager lacks the incentive to do so if permit expenditures and revenues are not part of his profit center. Hence, the closer a CCM is to the CEO, the more possibilities she should have to remedy problems of overlapping competences and ill-defined incentives.

The information we use is derived from responses to the questions "Is anybody responsible for dealing with climate change policies and energy and pollution reduction in the firm?" for which we recorded the manager title and "How far in the hierarchy is this manager below the CEO?" (cf. questions VI.1.a and VI.1.c in Appendix B). Out of 178 valid responses, 165 (92%) included the title of the manager in charge. Figure 1 provides an overview of the different functions these managers have. Roughly 75 managers are specializing in environmental issues, but most of them also occupy other functions, such as health & safety, quality manager, etc. From the last column it is evident that not even half of the environmental CCMs are dedicated exclusively to environmental issues. The second question enables us to construct a variable measuring the distance between the CCM and the CEO in terms of management levels. The variable takes a value of 0 if the CCM reports directly to the CEO, a value of 1 if there is a single hierarchy level between the CCM and the CEO, a value of 2 if two hierarchy levels separate them, and so on. The variable ranges between 0 and 5, and its mean and standard deviation are 1.1 and 0.9, respectively. The median and mode are equal to 1, i.e. in most firms of our sample there is a single management level

[22]Note that this need not be the manager we actually interviewed.

Figure 1: Main function of manager responsible for climate change issues



Notes: Bars represent the number of times a manager title contained the respective function. Multiple functions were possible and frequent. The last column reports the number of times a manager was exclusively decicated to environmental issues. Based on 178 responses.

separating the CCM from the CEO.

For further analysis we code dummy variables for the CCM title using the following four categories: (i) environment and energy, (ii) CEO or managing director, (iii) health, safety, and quality, and (iv) operations, production, and technical managers. Other functions are part of the omitted category. We also code a CCM dummy that equals 1 if a firm has a dedicated CCM and 0 otherwise.

4.2 Results

Tables 11 and 12 report the results from two sets of regressions. The results in Panel A are based on regressions of management practices on the CCM dummy and other controls. This tells us whether having a dedicated CCM affects management practices. The results in Panel B speak to the effect of organizational structure on management practices. The results were obtained by regressing different management variables on the distance to CEO variable and on the dummies for CCM categories, conditional on the firm having a dedicated CCM. All regressions include controls for the overall size of management, firm and respondent characteristics, and for interviewer noise.

Table 11: Organizational structure and management practices

	(1) overall climate friendliness	(2) energy monitoring score	(3) energy targets dummy	(4) energy targets score	(5) GHG monitoring score	(6) GHG targets dummy	(7) GHG targets score	(8) target enforcement score
Panel A: All firms								
CCM dummy	0.163**	0.776***	0.606**	0.435	-0.012	-0.257	-0.225	0.269
	(0.078)	(0.289)	(0.251)	(0.281)	(0.235)	(0.240)	(0.255)	(0.173)
Panel B: Firms with dedicated climate change manager								
distance to CEO	-0.093**	0.209**	-0.021	-0.001	-0.153	-0.139	-0.179	-0.016
	(0.037)	(0.086)	(0.096)	(0.143)	(0.107)	(0.099)	(0.115)	(0.097)
CCM responsibilities								
environment/energy	0.218***	0.199	0.361*	0.408	0.101	0.461***	0.471**	0.352**
	(0.069)	(0.154)	(0.189)	(0.254)	(0.173)	(0.164)	(0.197)	(0.170)
CEO/MD	-0.269**	-0.232	-0.674*	-0.579	-0.995***	-0.111	-0.169	-0.299
	(0.132)	(0.396)	(0.386)	(0.553)	(0.381)	(0.229)	(0.280)	(0.317)
health/safety/quality	0.013	-0.165	0.160	-0.014	-0.254	-0.125	-0.175	-0.070
	(0.067)	(0.162)	(0.195)	(0.258)	(0.193)	(0.164)	(0.198)	(0.179)
production/technical	-0.059	-0.172	-0.068	-0.213	-0.622***	0.220	0.233	-0.145
	(0.092)	(0.201)	(0.253)	(0.369)	(0.228)	(0.212)	(0.262)	(0.223)
share of managers	-0.387	0.056	-0.024	0.885	-2.099**	-0.831	-1.178	1.606
	(0.334)	(0.759)	(1.044)	(1.428)	(1.021)	(0.861)	(1.060)	(0.981)
plant size	0.183	0.791***	0.182	0.592*	0.213	0.120	0.075	0.851***
	(0.112)	(0.250)	(0.256)	(0.354)	(0.290)	(0.276)	(0.310)	(0.288)
observations	130	129	129	130	128	128	130	130
R-squared	0.512	0.476	0.316	0.360	0.426	0.364	0.329	0.431

Notes: OLS regressions of the overall index of climate friendliness (column 1) or normalized interview scores (column 2-8) on the climate change manager's (CCM) hierarchical distance to the CEO and a set of dummy variables for the CCM's main responsibility. Explanatory variables also include firm age (linear and quadratic), sector dummies, a constant, interviewer noise controls (dummies for interviewer identity and for experience less than 10 interviews), and respondent characteristics (dummy for technical background, post-interview scores for knowledge and concern about climate change issues). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 12: Organizational structure, climate policy and innovation

	(1) barriers energy efficiency	(2) CCA dummy	(3) CCA stringency score	(4) CT energy audit dummy	(5) ECA dummy	(6) R&D intensity score	(7) process innovation score	(8) product innovation score
Panel A: All firms								
CCM dummy	0.145	0.582**	0.478*	0.292	0.138	0.348	0.047	-0.247
	(0.230)	(0.235)	(0.285)	(0.304)	(0.263)	(0.316)	(0.205)	(0.234)
Panel B: Firms with dedicated climate change manager								
distance to CEO	0.370**	-0.094	-0.100	-0.197	-0.118	-0.070	-0.191*	-0.217*
	(0.147)	(0.100)	(0.143)	(0.132)	(0.092)	(0.126)	(0.105)	(0.114)
CCM responsibilities								
environment/energy	0.184	0.228	0.168	0.384**	0.549***	0.303	0.122	-0.222
	(0.239)	(0.195)	(0.304)	(0.193)	(0.172)	(0.207)	(0.189)	(0.190)
CEO/MD	0.791*	-0.387	-0.391	-0.999**	-0.163	-0.462	-0.680*	-0.685**
	(0.426)	(0.321)	(0.470)	(0.435)	(0.368)	(0.332)	(0.375)	(0.299)
health/safety/quality	-0.334	-0.268	-0.341	0.157	0.005	0.180	0.045	-0.330*
	(0.250)	(0.194)	(0.286)	(0.219)	(0.181)	(0.201)	(0.203)	(0.192)
production/technical	0.189	-0.325	-0.439	-0.110	0.351	0.271	-0.049	-0.275
	(0.335)	(0.257)	(0.381)	(0.284)	(0.217)	(0.248)	(0.249)	(0.254)
share of managers	0.764	0.510	1.240	-1.227	-1.297	1.221	-0.296	2.337**
	(1.192)	(1.102)	(1.768)	(1.311)	(1.034)	(1.115)	(1.118)	(1.021)
plant size	-0.648**	0.553**	0.920**	-0.433*	0.292	0.294	0.318	-0.078
	(0.294)	(0.247)	(0.357)	(0.254)	(0.265)	(0.264)	(0.247)	(0.226)
observations	107	119	119	127	115	129	127	125
R-squared	0.266	0.444	0.397	0.253	0.296	0.297	0.286	0.457

Notes: OLS regressions of normalized interview scores on the climate change manager's (CCM) hierarchical distance to the CEO and on a set of dummy variables for the CCM's main responsibility. Explanatory variables also include firm age (linear and quadratic), sector dummies, a constant, interviewer noise controls (dummies for interviewer identity and for experience less than 10 interviews), and respondent characteristics (dummy for technical background, post-interview scores for knowledge and concern about climate change issues). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Panel A shows that firms with a dedicated CCM have significantly more climate friendly management practices than those without such a manager. This result arises clearly for the overall index of climate-friendliness as well as for several practices and policies. In particular, we find that firms with a CCM are more likely to participate in a CCA and to adopt energy targets. They also do a better job at monitoring their energy usage than firms without a CCM. Conversely, there is no significant association of the CCM with GHG targets and GHG monitoring, with other voluntary schemes or with the innovation variables.

The estimates in Panel B highlight three systematic patterns of correlation which are evident in the coefficient estimates obtained for the overall index of climate friendliness in the first column. First, with respect to the qualitative aspect of organizational structure we find that firms whose CCM is an environment or energy manager have significantly more climate-friendly practices ceteris paribus. Second, firms whose CCM is closer in the hierarchy to the CEO are also more climate-friendly according to our index. Third, the effect of hierarchy is non-monotonic. While the negative coefficient on distance implies that climate-friendly practices improve as the CCM moves up in the hierarchy, the negative coefficient on the CEO/MD dummy implies that practices become worse again if the CEO himself/herself assumes the responsibilities of the CCM. This could be the case because multi-tasking leaves the CEO without a sufficient amount of time to attend to climate change issues or because these issues are one of the CEO's 'residual responsibilities' not assumed by any other manager, and hence are of low priority to the firm per se.

In order to find out what practices are driving these results, we ran the same regression for the individual scores underlying the index. The remaining columns in Panel B of Table 11 contain the results for the energy and GHG target variables. Panel B of Table 12 displays the results for the investment stringency, climate policy and innovation scores. We find that having an environmental or energy manager in charge of climate change issues is positively associated with the presence of targets for both energy consumption and GHG emissions – in the latter case there is also a positive association with the strigency of targets (cf. columns 3, 6 and 7 of Table 11). Target enforcement is also significantly higher in firms whose CCM is an environment/energy manager (cf. column 8 of Table 11). Furthermore, these firms are more likely to adopt voluntary climate policies such as the Carbon Trust energy audit and the ECA (cf. columns 4 and 5 of Table 12). The patterns of correlation between management practices and the dummy variables for the other functional CCM categories are less significant. The production/technical category of CCM enters the regression on GHG monitoring with a negative sign (cf. column 5 of Table 11) whereas the coefficient on the Health/Safety/Quality dummy is significant at 10% in the regression of the CCR product innovation score, also with a negative sign (cf. column 8 of Table 12). Overall, it seems that the qualitative effect of organizational structure is driven mainly by target setting and by the adoption of voluntary climate policies, both of which work better in firms whose CCM is an environmental/energy manager.

The interpretation of the coefficient on the dummy for CEO/Managing Director is slightly different from that of the other CCM dummies in that it compounds the qualitative and the hierarchy aspects.[23] Remarkably, this dummy enters all regressions consistently in the direction of lower climate friendliness, i.e. with a positive sign for the barriers to invest in energy efficiency score (in the first column of Table 12) and a negative sign in all other regressions. The coefficient estimate is statistically significant in the regressions of the GHG monitoring score (column 5 of Table 11), the Carbon Trust energy audit dummy (column 4 of Table 12) and the CCR product innovation score (column 8 of Table 12).[24]

The distance to CEO variable is positively associated with the energy monitoring score (cf. column 2 in Table 11) and with the barriers to invest in energy efficiency improvements (cf. column 1 of Table 12). It is negatively associated with the CCR process and product innovation scores at 10% significance (cf. columns 7 and 8 of Table 12). These results are consistent with the view that the CCM's place in the firm hierarchy determines the climate friendliness of management practices by constraining the range of practices that can be adopted. If interpreted in a causal fashion, our results suggest that a CCM who is at the lower end of the management hierarchy improves the firm's climate friendliness by implementing energy monitoring, i.e. at the *operational* level. In contrast, being high up in the hierarchy enables the CCM to improve the firm's climate friendliness by stipulating more favorable investment criteria for energy efficiency projects or by promoting innovation in climate-change related products, i.e. at a more *strategic* level.

As was the case for the overal climate friendliness index, we find that the positive effect that hierarchical proximity between the CCM and the CEO seems to have on climate friendliness turns

[23]By definition this manager's place in the firm hierarchy cannot vary across firms.

[24]It is also significant at 10% for the energy targets dummy, the barriers to energy efficiency investments score and for the CCR process innovation score.

around when the CEO herself/himself is in charge of climate change issues. Although not always statistically significant, we find this non-monotonic effect of hierarchy in all regressions expect the one for energy monitoring. This is due in part to the detrimental effects of multi-tasking but it could also reflect the fact that less climate friendly firms might assign climate change issues as a "residual" responsibility to the CEO.

5 Climate policy, management practices and innovation

The prevention of dangerous levels of global climate change requires substantial abatement of GHG emissions to take place over the next few decades (IPPC, 2007). As far as industrial emissions are concerned, moving firms to the efficiency frontier can provide only a limited amount of abatement unless innovating firms keep on pushing that frontier. In fact, if current climate policies in the UK are mainly geared at fostering innovation, this could explain why we fail to find a statistically significant correlation between various policy variables and energy intensity in the short run. Instead, one would expect to find a positive association between policy variables and innovation scores in the data.

This section sheds light on this issue by analyzing the link between management practices, policy variables and the three measures of innovation discussed above (see also questions VII.1-3 in Appendix B). As a validity check of the general R&D score, we compute the number of patents held in the year 2005 based on data from the European Patent Office (EPO) and regress the patent count on the overall R&D score. The results from the negative binomial regressions are displayed in Table 13. We find a robust positive correlation between the two variables even after conditioning on a number of control variables for sector, capital stock, firm and plant size, as well as interviewer dummies. In view of these results we are confident that the R&D score is informative about the firm's innovative output.

Table 14 summarizes the patterns of correlation between the three innovation variables and other variables in our survey. The table displays results from linear regression models where the different dependent variables are the score for climate-change related (CCR) process innovation (columns 1 and 2), the score for CCR product innovation (columns 3 and 4), and the score for the importance of general R&D in the company (columns 5 and 6). Each panel reports the estimated

Table 13: Correlation between R&D score and patent applications

	(1)	(2)	(3)
	number of patents in 2005		
general R&D	1.121***	1.178***	0.882***
	(0.211)	(0.343)	(0.339)
capital stock			-0.226*
			(0.121)
plant size			1.170**
			(0.550)
firm size			-0.501*
			(0.287)
3-digit sector controls	no	yes	yes
interviewer dummies	no	yes	yes
observations	183	183	155

Notes: Coefficients from negative binomial regression models. Standard errors in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%

coefficient and standard error from a regression of the dependent variable on a specific index or score from the survey data. The regression equation includes a full set of dummy variables for the firm's 3-digit SIC sector code to control for unobserved heterogeneity across sectors. Further, each specification is estimated first without (columns 1, 3 and 5) and then with capital stock (columns 2, 4 and 6) as an additional control.

Drivers In rows 1 and 2 we find that both types of CCR innovation are strongly correlated with both the degree of climate change awareness and the importance of CCR products for the firm. This reveals that managers reporting a high awareness of climate change also take real actions of strategic importance related to climate change. The insignificant coefficient estimates for general R&D suggest that the sample is well stratified, in the sense that not all R&D-intensive firms happen to be highly aware of climate change or producers of CCR products. The lack of a significant correlation between the competitive pressures index and innovation (cf. row 3) is in line with our finding that few firms expected strong effects of climate policy on competition and relocation in the first place.

Row 4 displays a strong positive correlation between "other drivers" and all types of R&D. Since this index is an average of the scores for investor and customer pressure, we also report the results from separate regressions for the two individual scores in rows 5 and 6. It seems that both factors have an effect of equivalent size. Moreover, the relationship is stronger for CCR process innovation than for CCR product innovation. Notice that the coefficient estimates for product

Table 14: Regressions of innovation scores on other management variables

		(1)	(2)	(3)	(4)	(5)	(6)
		innovation score					
		CCR process innovation		**CCR product innovation**		**general R&D**	
1	**awareness**	0.343**	0.301**	0.497***	0.500***	0.220	0.250
	(summary index)	(0.134)	(0.139)	(0.140)	(0.137)	(0.142)	(0.150)
2	**CCR products**	0.422***	0.395**	0.825***	0.762***	0.100	0.110
	(log score)	(0.146)	(0.154)	(0.160)	(0.183)	(0.179)	(0.198)
3	**competitive pressures**	0.080	0.100	-0.090	-0.130	0.140	0.150
	(summary index)	(0.070)	(0.070)	(0.152)	(0.158)	(0.128)	(0.139)
4	**other drivers**	0.429***	0.409***	0.342**	0.300**	0.371***	0.385***
	(summary index)	(0.101)	(0.110)	(0.132)	(0.151)	(0.118)	(0.133)
5	**customer pressure**	0.427***	0.357**	0.343*	0.280	0.392**	0.471**
	(log score)	(0.159)	(0.175)	(0.185)	(0.203)	(0.188)	(0.205)
6	**investor pressure**	0.464***	0.498***	0.408*	0.350	0.455**	0.434**
	(log score)	(0.172)	(0.176)	(0.212)	(0.251)	(0.18)	(0.206)
7	**energy targets**	0.387***	0.395***	0.040	0.110	0.291**	0.300**
	(summary index)	(0.102)	(0.113)	(0.137)	(0.165)	(0.119)	(0.135)
8	**GHG targets**	0.495***	0.439***	0.395**	0.368*	0.443***	0.432***
	(summary index)	(0.143)	(0.155)	(0.178)	(0.197)	(0.139)	(0.155)
9	**CCA stringency**	0.170	0.120	-0.120	-0.150	0.000	0.030
	(summary index)	(0.121)	(0.138)	(0.138)	(0.154)	(0.124)	(0.151)
10	**EU ETS**	-0.04	-0.1	-0.05	-0.02	0.287*	0.423*
	(summary index)	(0.18)	(0.218)	(0.157)	(0.191)	(0.170)	(0.237)
11	**Carbon Trust energy audit**	0.130	0.060	0.080	0.050	-0.080	-0.050
	(summary index)	(0.101)	(0.104)	(0.112)	(0.117)	(0.107)	(0.106)
12	**Enhanced Capital Allowance**	0.090	0.140	0.140	0.120	0.165*	0.170
	(summary index)	(0.117)	(0.122)	(0.158)	(0.175)	(0.092)	(0.104)
13	**barriers to energy efficiency**	-0.110	-0.160	0.220	0.340	-0.030	0.230
	(log score)	(0.435)	(0.467)	(0.397)	(0.470)	(0.409)	(0.426)
	3-digit sector controls	yes	yes	yes	yes	yes	yes
	controls for capital stock	no	yes	no	yes	no	yes
	observations	181	163	176	157	183	164

Notes: Each panel represents a different regression of a CEP Climate Change Management Survey Score on another survey variable and other controls. Each cell reports the estimated coefficient and standard error for the variable of interest. Standard errors are clustered at the firm level, i.e. robust to heteroskedasticity and autocorrelation of unknown form. All regressions include interviewer fixed effects. Variable names of survey scores are indented whenever the score is used in the calculation of the summary index preceding it. * significant at 10%; ** significant at 5%; *** significant at 1%.

innovation in columns 3 and 4 of row 4 are statistically significant whereas the corresponding estimates in rows 5 and 6 are not significant at the 5% level. This suggests that customer and investor pressure are complements in a firm's decision to undertake R&D in CCR products.

Measures Rows 7 and 8 display a strong positive correlation between CCR process innovation with both energy quantity targets and GHG targets. This is an intriguing finding and calls for a closer examination of the underlying mechanisms in future research. For example, it is possible that senior management embarks on a CCR R&D project and then sets tight energy quantity targets to strengthen the incentives for a successful outcome of the R&D project. Conversely, it could also be that stringent targets are implemented first, and that their presence induces the type of innovation that would be captured by the process innovation score. In view of our earlier finding that targets are also associated with higher energy efficiency, we conjecture that only those firms that have already picked the "low-hanging fruit" in terms of energy efficiency improvements need to conduct proper R&D to further reduce energy consumption by their production processes.

It is striking that CCR product innovation is positively correlated with GHG quantity targets but not significantly so with energy quantity targets. A straightforward explanation for the lack of correlation is that CCR product innovation reduces energy consumption of the firms' customers but does not necessarily help the firm itself to meet its energy quantity targets. In contrast, for a firm that tries to sell a CCR product it may be important to be perceived by their customers as "climate-friendly", and hence the presence of GHG targets and emissions monitoring is a vital part of their marketing strategy. Notice that, according to this idea, the directions of causation for process and product innovation are diametrically opposed in that stringent energy and GHG targets both cause *process* innovation, yet *product* innovation causes GHG targets.

In contrast to the strong positive association found above between the energy intensity of the firm and the score measuring barriers to invest in energy efficiency projects, the results in the last row of Table 14 show no statistically significant correlation between this score and any of the innovation scores. Hence, simple payback criteria may guide decisions on the adoption of existing technologies but they are inconsequential for the invention and commercialization of new products or processes. This is plausible because R&D spending is a long-term – often strategic – investment with uncertain returns for which simple rules-of-thumb hardly seem appropriate.

Policies There is no statistically significant correlation between the CCA index and any of the innovation variables (cf. Panel 9). This contrasts with the finding by Martin and Wagner (2009) that firms in a CCA filed significantly fewer patent applications than firms paying the full rate of the CCL after 2001. Controlling for unobserved effects that systematically vary with CCA participation status proved to be important in their study. Since our dataset is cross sectional we have less scope to control for unobserved heterogeneity. In Table 15 we seek to address this issue to some extent by adding more covariates, and by looking at the difference between the CCR innovation score and the general R&D score which controls for unobserved firm characteristics affecting both types of innovation. Panel 1 of Table 15 displays the results from regressions that control for size (capital stock, number of employees at the plant and in the firm) and for innovative capacity of the firm (number of patents in 2000). In columns 1 and 2 we look at general R&D, in columns 3 to 6 at CCR process and in columns 7 to 10 at CCR product R&D. The results on general and process R&D remain insignificant. For CCR product innovation we find negative coefficients which are significant at the 10% level, once we include more covariates. The results thus provide weak support for the hypothesis that the significant innovation effects found in Martin and Wagner (2009) are due to firms engaging in more CCR product R&D.

Participation in the EU ETS, analyzed in row 10 of Table 14, has no significant effect on CCR process or product innovation. The lack of an innovation impact of this EU wide policy can in part be explained by the low quota prices that have prevailed on the carbon markets so far, and in part by the high volatility of permit prices during phase I of the trading scheme (2005-2007). As is the case with other real options, uncertainty about future prices might induce firms to postpone irreversible investments in R&D. Similarly, firms may have been waiting for legal certainty about future tightening of ETS targets beyond the end of phase II in 2012 before spending resources on CCR R&D.

We do find a positive association between ETS membership and general R&D which is significant at the 10% level. However, additional results reported in Panel 2 of Table 15 show that this relationship is not robust to the inclusion of additional explanatory variables such as the number of patents held in 2000 as a proxy for the firm's knowledge stock. In contrast, a significant negative relationship emerges for CCR process R&D relative to overall R&D, implying that firms in the EU ETS substitute away from CCR process innovation towards other areas of innovation.

Table 15: Regressions of innovation scores on policy indices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
dependent variables	**general R&D**		**CCR process R&D**				**CCR product R&D**			
			level		relative to R&D		level		relative to R&D	
CCA	0.001	-0.020	0.173	-0.073	0.175	-0.066	-0.124	-0.433*	-0.109	-0.393*
(summary index)	(0.124)	(0.220)	(0.121)	(0.194)	(0.151)	(0.254)	(0.138)	(0.223)	(0.140)	(0.210)
capital		-0.047		0.135		0.197		0.131		0.174*
		(0.105)		(0.119)		(0.138)		(0.110)		(0.100)
patents held in 2000		0.023		-0.003		-0.025		0.048***		0.026**
		(0.014)		(0.009)		(0.015)		(0.012)		(0.012)
plant size		-0.066		0.105		0.177		0.193		0.276
		(0.268)		(0.324)		(0.300)		(0.351)		(0.266)
firm size		0.194		0.110		-0.048		0.049		-0.195
		(0.165)		(0.181)		(0.203)		(0.203)		(0.182)
EU ETS	0.287*	0.307	-0.043	-0.147	-0.335*	-0.454**	-0.050	-0.008	-0.327*	-0.311
(summary index)	(0.170)	(0.311)	(0.180)	(0.345)	(0.178)	(0.210)	(0.157)	(0.286)	(0.174)	(0.363)
capital		-0.021		0.163		0.184		0.123		0.148
		(0.128)		(0.114)		(0.155)		(0.111)		(0.123)
patents held in 2000		0.039***		-0.002		-0.041***		0.054***		0.015
		(0.011)		(0.012)		(0.014)		(0.015)		(0.016)
plant size		-0.036		0.154		0.190		0.131		0.178
		(0.256)		(0.302)		(0.268)		(0.327)		(0.261)
firm size		0.091		0.129		0.038		-0.095		-0.195
		(0.217)		(0.231)		(0.270)		(0.208)		(0.207)
Carbon Trust energy audit	0.097	0.211	0.201	0.108	0.138	-0.051	0.209	-0.004	0.111	-0.270
	(0.202)	(0.238)	(0.200)	(0.297)	(0.247)	(0.321)	(0.228)	(0.290)	(0.247)	(0.252)
capital		-0.046		0.185*		0.238		0.149		0.193
		(0.112)		(0.104)		(0.142)		(0.099)		(0.118)
patents held in 2000		0.024*		-0.005		-0.029*		0.044***		0.019
		(0.014)		(0.008)		(0.016)		(0.012)		(0.012)
plant size		-0.086		0.033		0.118		-0.018		0.086
		(0.256)		(0.287)		(0.279)		(0.304)		(0.263)
firm size		0.191		0.118		-0.029		-0.024		-0.238
		(0.180)		(0.184)		(0.213)		(0.207)		(0.182)
observations	166	120	164	120	163	119	160	117	159	116

Notes: All regressions include 3-digit sector dummies and interviewer dummies. Standard errors clustered at the firm level are reported in parentheses (i.e. robust to heteroskedasticity and autocorrelation of unknown form). *significant at 10%; ** significant at 5%; *** significant at 1%.

Row 11 of Table 14 shows that participation in an energy audit by the Carbon Trust is not associated with a significant change in any kind of innovative activity. This is consistent with the purpose of these audits, namely to identify opportunities for known types of energy efficiency improvements that come at close to zero cost. A robustness analysis in Panel 3 of Table 15 confirms this result, showing no significant impact of the audits on any of the innovation scores. The point estimates in row 12 suggest that beneficiaries of the Enhanced Capital Allowance innovate more, but none of them is statistically significant a the 5% level. This finding is not surprising as the allowance was granted for the adoption of existing technologies and not for R&D expenditures with uncertain outcomes. It is possible that the allowance freed up financial resources that firms subsequently deployed to R&D projects, yet this effect is not estimated precisely.

To sum up, this section has presented evidence that a number of climate friendly management practices are positively associated with climate friendly innovation. An important policy implication of this result is that some of the managerial factors that facilitate energy efficiency investments could also promote clean innovation, thus leveraging their beneficial effect. The empirical link between existing climate policies and innovation is weaker, which suggests that the design of these policies could be improved to align them with long-term mitigation objectives.

6 Conclusion

There is little doubt that policies aimed at reducing GHG emissions from the business sector must strengthen the incentives for improving energy efficiency. Firms can improve energy efficiency by adopting existing technologies or by inventing new technologies that are more energy efficient. The aim of this paper has been to shed new light on how a firm's management practices interact with both these channels, and to pin down specific organizational and managerial constraints that add to the technical difficulties associated with improving energy efficiency.

We have collected original data on management practices related to climate change by adapting an interview approach from the recent productivity literature for our purposes. The defining characteristics of this design are (i) to conduct "double-blind" telephone interviews with plant managers in a way that minimizes well-known types of survey bias, (ii) to consistently measure and compare climate-change related practices across firms controlling for systematic noise in the responses and (iii) to seek external validation of interview responses by matching them with independent data on business performance, including energy efficiency.

Our sample exhibits considerable variation in management practices, organizational structure, exposure to different government policies and other firm characteristics. Consistent with the "energy efficiency paradox", managers report what appear to be irrationally low payback times and that significant amounts of GHG emissions could be saved at zero incremental cost. We construct a summary index of all "climate friendly" management practices at the firm and show that it is positively associated with its energy efficiency and TFP. Analysis of individual practices reveals that the presence of targets on energy consumption is associated with higher levels of energy efficiency and TFP, while applying more stringent investment criteria for energy efficiency projects than for other investments is associated with lower levels of both measures. What is more, firms are less energy-intensive on average when they are pressed by their customers to reduce their GHG emissions. This is even more so when the firm's investors exert this pressure.

A number of managerial factors – including the management's awareness of climate change issues, targets for energy consumption or for GHG emissions as well as pressure from customers or from investors to adopt more climate friendly management practices – are also positively correlated with climate-change related process or product innovation. The relationship between climate-change related innovation and various existing climate policy measures is less clear. We find that process innovation *relative* to overall R&D efforts is lower at firms in the EU ETS while product innovation *relative* to overall R&D efforts is lower at firms that pay lower energy taxes by virtue of being in a UK CCA.

We also investigate how management practices correlate with the organizational structure of the firm. Organizational structure is characterized by the official title of the manager responsible for climate change issues and his or her hierarchical proximity to the CEO. We show that organizational structure explains a large part of the variation in management practices across firms. In particular, firms have more climate friendly management practices ceteris paribus if climate change issues are managed by the environmental or energy manager. This concerns the adoption of targets for both energy consumption and GHG emissions as well as the participation in voluntary policies aimed at improving energy efficiency. Moreover, hierarchical proximity of the climate change manager to the CEO is associated with firms adopting more strategic practices, such as product and process innovation related to climate change, as opposed to operational practices such as energy monitoring. Importantly, this effect is non-monotonic, in the sense that firms whose climate change manager is the managing director or CEO exhibit worse management practices ceteris paribus.

In summary, we have provided – through the collection of original data and subsequent matching to official performance data – new evidence on the empirical link between the organizational structure of a firm and the management practices it adopts on the one hand and its energy efficiency and responsiveness to climate change policies on the other hand. Management practices explain a great deal of the dispersion in energy intensity across firms within a sector, even after controlling for size, age, and other exogenous firm characteristics. This supports the view that the "energy efficiency paradox" – the observation that firms fail to adopt energy saving measures despite positive net returns – can be explained by managerial and organizational factors internal to the firm. Perhaps more important from a climate policy perspective, however, is our finding that several such factors are also associated with the firm's innovation of cleaner processes and products. While causal inference is beyond the scope of this study, we cautiously interpret our findings as evidence that management practices and organizational structure of a firm are crucial for its ability to use energy more efficiently both today and in the future, and to respond to public policy in this area.

Future research on this topic is likely to take three directions. First, the focus on a single country limits the variation in policy variables one can hope for. The limiting factor in expanding this work to other countries (besides researchers' resource constraints) must be seen in the availability of independent performance data, particularly on energy usage. Second, the empirical results of this paper will hopefully inspire research on more accurate models of energy use at the firm level that have testable implications. Finally, future research may be able to exploit exogenous variation that allows for causal inference in testing such models.

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Appendices

A Additional information on manager interviews

A.1 Interview process

We conducted structured telephone interviews with managers at randomly selected UK production facilities belonging to the manufacturing sector. The interview setup bears close resemblance to the innovative management interview design developed by Bloom and van Reenen (2007) in collaboration with a major management consulting company. The defining characteristics of this design are (i) to conduct "double-blind" telephone interviews with plant managers in a way that minimizes well-known types of survey bias, (ii) to consistently measure and compare climate-change related practices across firms controlling for systematic noise in the responses and (iii) to seek external validation of interview responses by matching them with independent data on business performance. In what follows, we provide additional information on the interview process which complements Section 2 of the paper.

Sampling frame

Interviewees were selected from a random sample of UK firms. In order to assure that the interviewers do not know anything about the company a priori, we focus on medium sized companies that are not household names. To this end, we used Bureau Van Dijk's ORBIS database (see http://www.bvdep.com) to download contact details for all UK firms that had more than 250 but less than 5000 employees in 2007. Next, the resulting list of more than 4000 companies was put in random order and split into batches of 100 firms. Each interviewer was given a batch and instructed to work down the list, one entry after another, without skipping.

Scheduling

Interviewers made "cold calls" to production facilities (not head offices), gave their name and affiliation and then asked to be put through to the plant manager. If a plant manager was not existent or not available, interviewers asked, successively, to speak to the production manager, chief operating officer, chief financial officer, or environmental manager. At this stage, the terms "survey" or even "research" were avoided as both are associated with commercial market research and some switchboard operators have instructions to reject such calls. Instead, interviewers said that they were involved with doing "a piece of work" on climate change policies, innovation and competitiveness in the business sector and would like to have a chat with someone in the field.

Once the manager was on the phone, the interviewer asked whether he or she would be willing to have a conversation of about 45 minutes about these issues. Depending on the manager's willingness and availability to do so, an interview ensued or was scheduled for another time. If the manager refused, he or she was asked to provide the interviewer with another contact at the firm who might be willing to comment. Managers who agreed to give an interview were sent a letter to confirm the date and time of the interview. The letter also contained background information on the researchers names and institutions and assured the managers that their responses were going to be treated as confidential. A similar letter was sent to managers who requested additional information before scheduling an interview.

Data collection

Interviewers were working on computers with an internet connection and accessed the central interview data base via a custom-built web interface that we programmed. The web interface includes a scheduling tool and an interview screen with hyperlinks to a manual that provides the analysts with background information on each question. For all interviews, the scheduling history as well as the exact time and date, duration, identity of interviewers and listeners etc. were recorded.

Approximately twenty pilot interviews were conducted between October and December of 2008 and led to several improvements of the interview structure. From January until mid March of 2009, an additional 190 interviews were conducted based on the final set of questions listed in Appendix B below.

A.2 Mitigating potential interviewer bias

Our approach differs from typical survey formats in that the task of scoring responses is relegated to the interviewers. This procedure is chosen in order to reduce known types of survey bias on

Figure 2: Double Scoring

Notes: The figure plots the average score given by the interviewer against the average score given by another analyst listening to the interview, using data from 65 interviews that were 'double scored' in this way. The average score is computed as the unweighted mean of the raw scores for all 21 ordinally scored questions. Fitted values are obtained from an OLS regression of the interviewer average score on listener average score.

the part of the respondents. However, one might worry that the interviewers' preconceptions about the firms they interview might influence the score, especially in the case of brand-name products and/or large multinational firms. We seek to minimize such bias by focusing on mid-size firms which are less likely to fit this category. Moreover, in the regression analysis we use interviewer fixed effects to control for interviewer-specific noise inducing serial correlation in the scores. Further controls are included for the interviewer's experience and for the respondent's characteristics such as educational background, overall knowledge about the issues discussed and attitude towards climate change.

In order to verify that the response score is not just pure noise but carries a discernible signal we conducted several interviews for which an additional team member listened in and independently scored the answers. For each of the 21 questions that were scored in an ordinal fashion Table 16 reports the correlation coefficients between the two scores recorded (in column 1) as well as the relative frequency of identical scores (in column 2) or almost identical scores (in column 3), where the latter allows for a tolerance of ± 1. The correlation coefficients range between 0.61 and 0.94, and the proportion of equal scores is well above 50% in the majority of cases. Figure 2 summarizes this information by plotting the average score given by the person running the interview against the average score given by another person listening to the interview. The plot is based on the 65 firms whose interviews were 'double-scored' in this way and shows a strong positive relationship with an almost 45-degree regression line. A Spearman test for rank correlation gives a correlation

Table 16: Correlation between interviewer and analyst scores for 'double scored' interviews

	(1) correlation	(2) proportion of equal scores	(3) proportion of score difference ≤1
adaptation to climate change score	0.78	80.0%	89.2%
awareness of climate change score	0.80	52.3%	92.3%
barriers to investments in energy efficiency score	0.71	75.4%	86.2%
CCA stringency	0.63	66.2%	83.1%
climate-change related products score	0.70	60.0%	86.2%
competitive pressure due to climate change score	0.79	64.6%	90.8%
competitive relocation due to climate change score	0.82	83.1%	93.8%
customer pressure score	0.81	56.9%	90.8%
energy consumption targets score	0.82	53.8%	89.2%
energy monitoring score	0.71	44.6%	84.6%
target enforcement score	0.84	53.8%	87.7%
rationality of behaviour on ETS market score	0.77	90.8%	95.4%
stringency of ETS target score	0.94	92.3%	96.9%
GHG monitoring score	0.85	70.8%	83.1%
GHG emissions targets score	0.89	64.6%	72.3%
investor pressure score	0.75	50.8%	76.9%
process innovation score	0.67	53.8%	86.2%
product innovation score	0.71	61.5%	84.6%
purchasing choices score	0.82	61.5%	92.3%
Research and Development - broad innovation score	0.74	53.8%	92.3%
measures on site score	0.61	38.5%	90.8%

Notes: The table compares the numerical scores given by the interviewer to those given by an analyst who listened to the interview for each of the questions graded on a scale from 1 to 5. Column 1 reports the correlation coefficient. Column 2 reports the relative frequency of the event that both analysts gave the same score and column 3 the relative frequency of the score difference being at most 1.

coefficient of 0.746 and the hypothesis of no correlation can be rejected at the 1% significance level. We thus conclude that the scores are a noisy but informative measure of the interviewee's responses.

A.3 Distribution of the z-scores

Figure 3: Distribution of z-scores

B Questionnaire

Questions	Values	Coding description
I. Climate Change Awareness		
1. Awareness of climate change issues		
(a) Are climate change topics being discussed within your business? Can you give examples? (b) Are climate change related issues formally discussed in management meetings? Can you give an example? (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	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 CC is an important part of the business strategy.
Mentioned positive impact	yes, no	
2. Climate-change related products		
(a) Do you currently sell climate-change related products? (Products that help your customers to reduce GHG emissions or adapt to climate change) (b) Can you give examples? (c) How important is that as a source of revenue within your firm?	1-5, dk, rf	Low: No CC related products Mid: Some CC related products. These products are however not the main profit or revenue source of the firm High: The majority of the firm's output can be considered a climate-change related product
II. Compulsory policies		
1. ETS		
1. Stringency (a) Is your company (or parts thereof) regulated through the European Union Greenhouse Gas Emissions trading system? (b) Since when?	no, 2005-2009, yes dk year, dk, rf	
2. (a) How stringent is the emissions cap/quota imposed by the ETS? (b) Can you describe some of the measures you had to put in place to comply with the cap?	1-5, dk, rf, na	Low: CAP is at business as usual Mid: Some adjustment seem to have taken place, however nothing which led to fundamental changes in practices; e.g. light bulbs, insulation etc. High: Measures which led to fundamental changes in production processes; e.g. fuel switching; replacement of essential plant and machinery
3. By how much does the ETS cap/quota require you to reduce your emissions by 2012 (relative to when you joined ETS)?	percent	
4. Did you buy or sell emission rights via the ETS?	no because of image concern, no because no capacity, no other, bought, sold, both, dk, rf	
5. Rationality of market behaviour (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 emission 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, and just buy or sell whatever the excedent is. Permit trading decision is centralised. Mid: Are in the process of learning how the market works and in the first years did not take 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 abatement cost curve. Trading is used as a tool to reduce compliance cost and to generate extra revenue from excess abatement. Moreover, company forms expectations about permit price and re-optimizes abatement choice if necessary.

2. Participating in CCA

1. (a) Is your company (or parts thereof) subject to a UK Climate Change Agreement? (b) Since when?	No, 2000-2009, yes dk year, dk, rf, na		
2. (a) How stringent is the target imposed by the CCA? (b) Can you describe some of the measures you had to put in place to comply with the cap?	1-5, dk, rf, na	Low	Target corresponds to business as usual
		Mid	Some adjustment seem to have taken place; however nothing which led to fundamental changes in practices; e.g. light bulbs, insulation etc.
		High	Measures which led to fundamental changes in production processes; e.g. fuel switching; replacement of essential plant and machinery.
3. Did you buy or sell emission rights via the UK ETS?	no because of image concern, no because no capacity, no other, bought, sold, both, dk, rf, na		
4. By how much does the CCA target require you to reduce your energy consumption or carbon emissions by 2010 (relative to when you joined the CCA)?	percent, target (relative, absolute), type (energy target, carbon target, dk)		

III. Drivers - Competitive Pressures

1. Competitive impacts of climate change policies

(a) Are you more or less affected than your competitors from climate change policies? (domestic, international or both, depends on where the competitors are) (b) Can you give an example? Can you explain why?	1-5, dk, rf	Low	Negative effects; i.e. competitors face significantly less regulation or are in a better position to adjust to the same regulation; examples: major competitors are abroad where no regulation applies; competitor can more cheaply switch to less polluting technology
		Mid	All competitors face same regulation (or, the firm has no competitors)
		High	Positive effects; e.g. competitors face stronger regulation; competitors have more difficulty in adjusting to the same level of regulation

2. Relocation because of climate change policies

1. (a) Are you considering relocating or outsourcing production abroad in response to climate change policies? (current or expected) (b) How concrete are these plans? (c) How many jobs will this affect?	1-5, dk, rf	Low	No plans for relocation
		Mid	Some plans to relocate parts of production abroad. Evidence that plans are concrete; e.g. detailed knowledge of which parts and to where
		High	Complete relocation of the site imminent
2. Mentioned relocation for other reasons (if did not mention anything, leave blank)	text box		

IV. Drivers - Other

1. Customer pressure concerning climate change

(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	Nothing required
		Mid	Customers ask for some improvements on energy efficiency and look for a "climate friendly" product, but they do not expect or require data as proof. Labelling the product as "green" is enough to satisfy customers preferences
		High	Customers consistently ask for certified data on emissions during production or usage. A customer friendly system to recognize the best products in term of energy efficiency is often available in the market (e.g. EU energy efficiency grade for home appliances)

2. Investor pressure concerning climate change

(a) Are your investors concerned about your GHG emissions? (b) How do they voice this concern? (c) Did your investors require hard data on your carbon emissions? (d) Did they impose targets or specific measures to reduce GHG emissions?	1-5, dk, rf	Low	Nothing required
		Mid	Investors raise the issue of climate change and demand reporting on pollution. Some evidence would be good; e.g. issue was raised at last Annual General Assembly
		High	Investors demand concrete measures to reduce pollution

V. Measures

1. Energy monitoring

(a) How detailed do you monitor your energy usage? (b) How often do you monitor your energy usage? (c) Describe the system you have in place.	1-5, dk, rf	Low	No monitoring apart from looking at the energy bill
		Mid	Energy monitoring as opposed to looking at the energy bill
		High	Detailed energy monitoring in space and time; e.g. hourly monitoring of power or gas used by production line

2. GHG monitoring

(a) Do you explicitly monitor your GHG emissions? (b) Do you account for GHG emissions embedded in your supply chain? How? (c) Are you GHG figures externally validated?"	1-5, dk, rf	Low	No specific
		Mid	Detailed energy monitoring with clear evidence for carbon accounting (at firm level)
		High	Carbon accounting of both direct and indirect emissions (supply chain emissions); External validation of GHG figures

3. Existence and stringency of targets on energy consumption for management

1. (a) Do you have any targets on energy consumption which management has to observe? (e.g. kWh of electricity)	no target, relative and/or absolute quantity target, only expenditure target, dk, rf		Type of target
(b) Can you describe some of the challenges you face in meeting the targets? (c) Do you think these are stringent targets? How likely is it that you meet those targets?	1-5, dk, rf	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
2. Approximately by how much does this require reducing your current energy consumption in the next 5 years (10%, 25%, 50%)?	percent		
3. Since when are you having these targets?	2000 (or earlier), 2001-2010, dk, rf, na		

4. Stringency of targets on GHG emissions for management

1. (a) Do you have any targets on greenhouse gas emissions in addition or instead of targets on energy? (e.g. on tonnes of CO2 emitted)	no target, direct emissions, direct and indirect emissions, dk, rf		Type of target
(b) Can you describe some of the challenges you face in meeting the targets? (c) Do you think these are stringent targets? How likely is it that you meet those targets?	1-5, dk, rf	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
2. Approximately by how much does this require reducing your current emissions in the next 5 years (10%, 25%, 50%)?	percent		
3. Since when are you having these targets?	2000 (or earlier), 2001-2010, dk, rf, na		

5. Target Enforcement

(a) What happens if 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, na	Low	No targets or missing targets does 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 do not get bonus; carbon credits have to be bought

6. Emission reducing measures on site

(a) Did you take any concrete measures to reduce greenhouse emissions? (b) Can you give specific examples?	1-5, dk, rf	Low	No measures taken to reduce direct or indirect emissions
		Mid	Company makes some effort to reduce direct emissions (GHG) and indirect emissions trying to reduce energy consumption on site or using electricity produced by renewable source of energy
		High	Company adopts best available practices to reduce emissions. It uses electricity produced by renewable sources of energy or produce electricity on site (e.g. geothermal energy). It reuses excess energy from the production process for co-generation of heat (e.g. to heat indoor spaces, to sell it to surrounding companies/households or to produce electricity to be fed back into the grid)

7. A recent emission reducing measure

1. Did you recently implement an emission reducing measure? When? If there were several, can we discuss the one that had the biggest impact on emissions?	2000 (or earlier), 2001-2010, dk, rf, na	
2. Describe what it was all about?	text box	
3. How much did this single measure reduce your (total) energy consumption?	percent	
4. How much did this single measure reduce your (total) GHG emissions?	percent	
5. How did you learn about this measure?	consultant, government, customer, supplier, employee, R&D project, competitor, other, dk, rf, na	
If other, please explain	text box	
6. What motivated the adoption of this measure?	EU ETS, energy cost saving / high profitability, pollution saving, reputation, customer pressure, employee initiative, public investment support, compliance with regulation, compliance with expected future regulation, other, dk, rf, na	
If other, please explain	text box	

8. Barriers to adopting energy-efficiency investments

1. Can you give examples of measures to enhance energy efficiency which were considered but eventually not adopted? (take note here whether talks about lighting, space heating, AC, stand-by consumption etc.)	text box		
2. To the extent that this decision was based on the expected economic return of such measures, can you tell me what hurdle rate (in percent) or payback time (in years) was used to reject?	1-5, dk, rf	1	<=10 %
		2	11-20 %
		3	21-40 %
		4	41-100 %
		5	>100 %
	1-5, dk, rf	1	0-2 years
		2	3-5 years
		3	6-8 years
		4	9-15 years
		5	>15 years
3. Is this [hurdle rate/payback time] criterion more, less or equally stringent than the one applied to non-energy related measures to cut costs?	1-5, dk, rf, na	Low	Much less stringent
		Mid	Equal
		High	Much more stringent
4. If different: Why?	text box		
5. What other factors were influential in the decision?	text box		

9. Further reductions

(a) By how much could you - at current energy prices - further reduce your current GHG emissions without compromising your economic performance? (i.e. how much more emission reduction could be achieved without increasing costs)	percent
(b) What further GHG emission reduction would be technologically possible (although not necessarily at no extra cost)? Notes: Assuming that production stays constant. This should not include emission reduction achieved by switching to renewable electricity. Include emissions reductions through CHP however.	percent

10. 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?

Policy measures	***Participated***	***Appreciation***
1. Carbon Trust Online Tools (Benchmarking Tools, Action Plan Tool)? When?		
2. Carbon Trust Energy Audit or Advice? (CTaudit)		
3. Innovation grants from the Carbon Trust? When?	no, 2001-2009, yes dk year, dk, rf, na	dk, useful, not useful
4. Carbon Trust Standard		
5. Enhanced Capital Allowance scheme? (ECA)		
6. Anything else? (other)	text box	

VI. Measures - Management

1. Current Responsibility for Climate Change issues

(a) Is anybody responsible for dealing with climate change policies and energy and pollution reduction in the firm? (if several take highest ranking manager)	yes, no, dk, rf
Manger title if mentioned	text box
(b) What other responsibilities does this manager have?	no other roles, production, health/safety/environment, accounting/finance, other
If other, please explain	text box
(c) How far in the hierarchy is this manager below the CEO? (figure out through sequential questioning if necessary)	CEO, 0-10, dk, rf, no clear responsibilities

2. Past Responsibility for Climate Change issues

(a) Has there recently been a change in responsibilities for climate change issues? When?	no change, 2000-2010, yes dk year, dk, rf
(b) Who - if anybody - was responsible for dealing with climate change policies and energy and pollution reduction in the firm before that change?	yes, no, dk, rf
Manger title if mentioned	text box
(c) What other responsibilities did this manager have?	no other roles, production, health/safety/environment, accounting/finance, other
If other, please explain	text box
(d) How far in the hierarchy is this manager below the CEO? (figure out through sequential questioning if necessary)	CEO, 0-10, dk, rf, no clear responsibilities

VII. Measures - Innovation

1. Importance of Research & Development in the firm

(a) Is there much Research & Development activity carried out within your firm? (either in-house or by commissioning external partners or overseas branches) (b) Do you devote some staff time or other resources to create new ideas, extra knowledge? Do you try to improve both what you produce and how you produce it? (c) Do you have a dedicated R&D department? (d) Can you give examples of some recent projects? (e) What fraction of revenues are used for that? (more than 1% would be a big) (f) What fraction of your products are new (less than 5 years old)?	1-5, dk, rf	Low: No R&D activity at the firm Mid: Some activity, for example does not have a properly speaking R&D department, but staff new ideas are evaluated (internal competition). New ideas are followed-up and management discuss them High: Highly R&D intensive firm
(g) Is this R&D activity taking place at the current site?	yes, no, dk, rf	
(h) If this R&D activity is mainly taking place at another site, in which country is this site located?	list of countries, dk, rf	

2. Climate-change related process innovation (helping to reduce company GHG emissions)

(a) Are some of these resources (R&D department, staff time, other projects) used to develop/implement new ways of reducing the GHG emissions related to the production process? (b) Can you give examples? (c) What fraction of your Research & Development funds are used for that? (less than 10%, more than 10%?) (d) Are you having other "green" R&D projects?	1-5, dk, rf	Low: No R&D funds 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 (if they can provide a figure on the share it's probably a 5)
(e) Is this R&D activity taking place at the current site?	yes, no, dk, rf	
(f) If this R&D activity is mainly taking place at another site, in which country is this site located?	list of countries, dk, rf	
(g) Mentioned other (non GHG related) environmental process innovation projects	text box	

3. Climate-change related product innovation (helping your customers to reduce GHG emissions)

(a) Are you trying to develop new products that help your customers reducing GHG emissions? (b) Can you give examples? (c) What fraction of your Research & Development funds are used for that? (less than 10%, more than 10%?)	1-5, dk, rf	Low: No R&D funds committed to reducing GHG emissions Mid: GHG emission reductions are a secondary objective for at least some R&D projects High: The company has major R&D projects that try to find low-carbon production processes or new products related to climate change; e.g. clean tech products such as solar panels; fuel cells etc.
(d) Is this R&D activity taking place at the current site?	yes, no, dk, rf	
(e) If this R&D activity is mainly taking place at another site, in which country is this site located?	list of countries, dk, rf	
(f) Mentioned other (non GHG related) environmental product innovation projects	text box	

VIII. Other Measures

1. Emission awareness purchasing

(a) Do GHG emissions matter for purchasing and investment decisions? How? (b) Do you routinely gather data about GHG emissions implied by different purchase and investment options? (c) Was there an example in the past where you choose one option over another on the grounds that it had less GHG impacts?	1-5, dk, rf	Low	No information about energy efficiency or GHG emission impact available when making purchasing and investment decisions
		Mid	Information about energy efficiency and/or GHG emissions is routinely gathered when making purchasing and investment decisions
		High	Evidence that GHG emissions can determine decision making

2. Voluntary offsetting

1. Is your company engaging in any voluntary carbon offsetting schemes?	yes, no, dk, rf
2. Approximately, what fraction of your GHG emissions do you offset?	percent
3. Do you rely on third party brokers for offsets or do you run your own schemes?	third party, own schemes, dk, rf

3. Adaptation

(a) Do you have any measures in place that are responses to actual or expected effects of climate change? (b) Can you give examples?	1-5, dk, rf	Low	No adaptation measures in place
		Mid	Some basic awareness and planning to address such risk Notes: E.g. flood protection or adaptation to higher temperatures trough cooling systems etc.. Equally it might include taking out insurance against climate change risks
		High	Wide range of measures in place to respond to climate change risks and threats

IX. Firm and Plant Characteristics

1. How many people are employed in the firm (globally)?	#	
2. How many people does the firm employ in the UK?	#	
3. How many people are employed at current site?	#	
4. What percentage of site employees are union members?	percent	
5. Has ownership changed in the last 2 years?	yes, no, dk, rf	
6. Is the firm ultimately owned by a multinational company? Country of ultimate owner?	no, list of countries, dk, rf	
7. How many sites does the firm operate (globally)?	#	
8. How many sites does the firm operate in the UK?	#	
9. When did operations in the current country start?	year	
10. What fraction of your running costs are for energy?	percent	
10b. (if they can't answer 10) What fraction of your turnover are for energy?	percent	
11. Energy Bill (only ask if 11 you cannot figure out Q10 directly)	#	000 (thousands of local currency)
12. Total running costs (wage cost + materials) (only ask if 12 you cannot figure out Q10 directly)	#	000 (thousands of local currency)
13. What is the site carbon pollution (if mentioned before that they monitor)? (annual; last available figure; in tons of CO2)	# units	
	direct, indirect, travel, distribution	what it includes
Direct emissions (d)	#	
Indirect (embedded in intermediates)	#	
Executive Travel (x)	#	
Distribution (b)	#	
14. How many times did you get inspected for compliance with environmental regulation by the government in the last 5 years?	#	
15. Does your company purchase renewable power?	yes, no, dk, rf	
What fraction of total consumption?	percent	
16. Site has environmental management system (ISO14000)	yes, no, dk, rf	
17. Number of competitors globally (including UK)?	#	
18. Number of competitors in current country?	#	
19. Share of site output for export	percent	
20. Share of site inputs imported	percent	
21. What percentage of site employees are managers?	percent	
22. What percentage of site employees have a university college degree?	percent	

X. Post Interview

1. Interview duration (mins)	#	
2. Interviewers' impression of interviewee's reliability	1-5, dk, rf	1 Some knowledge about his site, and no knowledge about the rest of the firm 3 Expert knowledge about his site, and some knowledge about the rest of the firm 5 Expert knowledge about his site and the rest of the firm
3. Interviewee seemed concerned about climate change	1-5, dk, rf	1 Not concerned 3 Somewhat 5 Very concerned
4. Interviewee seemed skeptic about action on climate change	1-5, dk, rf	1 Not sceptic at all 3 Somewhat sceptic 5 Very sceptic
4. Mentioned other climate change related policies	text box	
5. Moaned a lot about high energy prices	no, a little, a lot	
6. Number of times rescheduled (0=never)	#	
7. Seniority of interviewee	1-6	1 Director 2 VP/General Manager 3 Plant/Factory Manager 4 Manufacturing/Production Manager 5 Technician 6 (Environmental), Health & Safety Manager
8. Age of interviewee (don't ask, guess!)	#	
9. Gender of interviewee	male, female	

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