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Management Practices and Climate Policy in China

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MANAGEMENT PRACTICES AND CLIMATE POLICY IN CHINA*

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Abstract

We investigate how management quality moderates the impact of carbon pricing on Chinese firms. Based on interviews with managers and lead engineers at manufacturing firms in Hubei and Beijing, we construct a novel index on climate-change related management practices and link it to firm data from various sources. We document higher average productivity and more green innovation among firms that are well managed according to this index. In an event study of the introduction of regional cap-and-trade schemes for CO_2, we analyze how these management practices interact with treatment. While treated firms reduced coal consumption more than control firms, this effect is statistically significant only for well-managed firms. The reduction could have been 25% greater if badly managed firms had been well managed. Our study highlights that good management practices, in particular energy monitoring, enhance the effectiveness of market-based climate policies by enabling firm to rationally comply with them.

Keywords: climate policy; firm behavior; management practices; emissions trading scheme; policy evaluation

JEL Classifications: D22, O31, Q48, Q54

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1 Introduction

China's role as the world's manufacturing powerhouse and its strong dependence on fossil fuels have made it the world's largest emitter of CO_2, with a share of 31% in global emissions (data from Global Carbon Project, 2021). Consequently, international efforts to avoid dangerous climate change critically depend on China taking drastic action to slow down and revert the rapid growth in its emissions over the past decades. Recently, the country has pledged to achieve carbon neutrality by the year 2060. Taking an important step towards achieving this ambitious goal, China launched a national carbon market for the electricity sector in July 2021, which will be gradually extended to industrial polluters.

Market-based instruments like cap-and-trade promise greater efficiency than more prescriptive ways of regulating pollution, but they unfold their full potential only if market participants fully understand the trade-offs between using, selling or banking a pollution permit. Trading decisions are hence not trivial and cannot just be delegated to external brokers, either. Making optimal abatement choices requires a manager to have profound knowledge of all available options to curb emissions and to identify those with least cost. Taking an optimal banking decision additionally necessitates forecasting which abatement technologies might become available in the future, and at what cost. Whether to procure this technology from another firm or to conduct R&D within the firm is another strategic business decision that managers can hardly delegate. Therefore, a firm's fortune in the carbon market depends on the attitude and aptitude of its management. By the same token, the success of China's national carbon market at minimizing overall abatement costs and fostering low-carbon investment and innovation, will depend to no minor degree on the quality of its management resources. Despite its policy relevance, this topic has received little attention in the literature thus far.

This paper provides the first empirical evidence on how greener management practices moderate responses to carbon pricing by firms that participated in pilot emissions trading schemes (ETS) located in the city of Beijing and Hubei province. Introduced in 2013 and 2014, respectively, these two schemes (out of a total of seven regional pilots) are well suited for analyzing performance aspects of the nationwide ETS. Beijing, the spearhead of China's rapid economic development, has earned a dubious reputation as one of the world's most polluted capital cities (Hu et al., 2013). Hence, climate policies in Beijing have been designed in part with an eye to reaping air pollution co-benefits, and this is likely to leave its mark on the regulation that is being rolled out nationwide (Qian et al., 2021). Hubei province has the largest carbon market, both in terms of total value and market volume (Welfens et al., 2017). Given its heavy industrial structure and high GDP growth, the province is very representative of the Chinese economy and hence provides an ideal test bed for predicting the impacts of a national carbon pricing scheme.

Since data on management practices are not provided by official sources, we collect new data by interviewing plant managers or lead engineers at 216 randomly selected firms. Interviews were conducted over the phone, following the double-blind approach pioneered by Bloom & van Reenen (2007) in the World Management Survey (WMS). Unlike the WMS, which focuses on general management practices, our data collection effort builds on earlier work by Martin et al. (2012, 2014a) and measures 'climate-centric' management practices, e.g. those related to energy consumption, innovation, pollution and emissions control for greenhouse gases (GHG), including cap-and-trade, and other relevant aspects.

The first part of our empirical analysis documents how these management practices correlate with firm performance. After aggregating all climate-centric management practices into a pertinent measure of management quality -the 'climate change management index'- we show that firms with better climate-centric management have on average higher turnover, even after controlling for capital, materials and labor inputs. A one-standard-deviation increase in management quality is associated with a 7.8% improvement in productivity. With respect to low-carbon investment, we correlate the information provided by managers with data on "green" patents filed by the firm. Both the share and presence of such patents are strongly positively associated with the climate change management index, which underlines the credibility of the information elicited in the survey for measuring climate-centric management practices.

We then investigate whether carbon trading affects energy use of regulated firms, giving particular attention to treatment heterogeneity across different tiers of management quality. Our estimation results indicate that the launch of the pilot ETS in Beijing has reduced consumption of coal by treated firms relative to control firms, but this effect is statistically significant only for well-managed firms in the above-defined sense. Our estimates imply that the overall reduction in coal use following the introduction of the pilot ETS would have been 25% larger (57% instead of 46%) if *all* ETS firms had adopted climate change related management practices above the median firm. An analysis of individual climate-centric management practices reveals that energy monitoring plays a major role and explains about half this effect. Moreover, we document a positive association between climate friendly management practices and rational trading behavior on the carbon market.

Our paper provides first evidence that better climate-related management practices can leverage the effect of market-based instruments for climate change regulation in China. This finding is policy relevant and timely, given that the country's nation-wide ETS has already surpassed the European Union Emissions Trading Scheme (EU ETS) and become the world's largest carbon market. With China being the world's largest emerging economy, our analysis is also relevant for more than half-a-dozen other emerging economies that are considering the adoption of cap-and-trade policies for GHG emissions. Our paper breaks new ground by connecting the new empirical management literature with an emerging program evaluation literature estimating causal impacts of climate change regulation on business in other parts of the world. Only by linking these two strands of the literature can we gain a better understanding of how managerial awareness of innovative approaches to mitigate GHG emissions, as well as the ability to implement them, translates into socially desirable outcomes of climate policy.

The paper is structured as follows. The next section describes the policy background and discusses the related literature in detail. Section 3 describes the interview process and additional data collection. Section 4 explores the relationship between management and firm performance. Section 5 presents the results on the pilot ETS and counterfactual analysis. Section 7 concludes.

2 Policy Background and Related Literature

2.1 Carbon Trading in China

In 2011, China announced that it would use cap-and-trade as a policy instrument to mitigate GHG emissions. Ten years later, on 16 July 2021, China launched its national carbon market which, in its first stage, encompasses 2,162 electricity generators emitting 4.5 billion tons of CO_2 per year (Liao & Yao, 2022). This amounts to about three times the current amount of emissions capped in the EU ETS and establishes China's ETS as the world's largest carbon market.[1] To support the development of the national ETS, the Chinese government launched between 2013 and 2014 separate pilot schemes in five cities – Shenzhen, Shanghai, Beijing, Tianjin, and Chongqing – and two provinces – Hubei and Guangdong. For simplicity, we will henceforth refer to cities and provinces alike as "regions". The seven pilot ETS continue to operate in parallel with the national ETS. In total, they cover approximately 1.2 billion tons of CO_2, roughly corresponding to 16% of CO_2 emissions and 20% of total energy use in China (Jotzo & Löschel, 2014, Stoerk et al., 2019). The bulk of the ETS-regulated firms belong to energy-intensive industries such as power and heat, cement, chemicals, iron and steel, as well as several non-industrial sectors such as hospitals, hotels and buildings (Qi et al., 2014, Munnings et al., 2016). Since the design of the schemes was not uniform across provinces, there is some variation in the inclusion criteria for firms to be regulated. Participation thresholds for firms, when included, are based on annual CO_2 emissions or energy consumption in a reference period (for example, 2009-2011) and range between three thousand and 20 thousand tons of CO_2 (Zhu et al., 2019). In the two pilot schemes analyzed below, the initial participation thresholds for firms located in Beijing and Hubei provinces were ten thousand tons of CO_2 and 60 thousand tons of coal equivalent (tce), respectively.

The Chinese national carbon market is a rate-based market where allowances are not subject to an absolute cap but issued in fixed proportion to output. This al-

[1] The EU ETS emissions cap for 2021 from stationary installations is 1,571,583,007 tons of CO_2 emissions. See https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/emissions-cap-and-allowances_en, last accessed July 5, 2023.

lows total emissions to fluctuate with actual output. In contrast, the pilot schemes used absolute caps as in Europe and California, except for a few sectors. In our sample, intensity targets were relevant only to firms in the power and heat sector, as well as for cement firms located in Hubei.[2] The majority of firms in our sample thus faced an absolute emissions cap. Whether management quality differentially affects a firm's response to the ETS when faced with an absolute or relative emission target is an empirical question that we shall address in Section 5.1 below.

2.2 Related Literature

Recent studies of China's carbon market pilots highlight two stylized facts about their performance. First, carbon prices vary substantially across the pilot schemes, though average prices have generally been low. Fan & Todorova (2017) and Zhang et al. (2017) have documented that the average market price across seven pilots fluctuated between 0 and 125 RMB (i.e., 0-16.3 Euros). While much lower than EPA's social cost of carbon estimate, carbon prices in the Beijing and Hubei ETS, depicted in Figure B.3 in the appendix, were comparable though to those observed in the European carbon market up until 2018.

Second, market liquidity has been low. The most active market was in Shenzhen, where the cumulative trading volume accounted for only 5.57% of the cap over the period from June 2013 to November 2014. Zhao et al. (2016) report that there are no transactions in nearly one-third of the trading days in the pilot markets, with trading volumes spiking near the compliance deadline. This was also the case in Beijing and Hubei, as can be seen from the time-series plots of trading volumes displayed in Appendix Figure B.3. Low liquidity could be the result of transactions being made only for compliance purposes. This would mean that firms with long positions have failed to associate carbon trading with their energy conservation management and, possibly, to capitalize on the allowance surplus. Both stylized facts are consistent with the assessment by Zhang et al. (2017) that compliance in the pilot schemes imposed only "soft constraints" on the regulated

[2]See the allowance allocation rules in Annex 3 of Beijing Development and Reform Commission (2013), and Hubei Development and Reform Commission (2015).

firms.

An emerging empirical evaluation literature has produced evidence that the pilot schemes have indeed reduced firm emissions. Using firm-level energy consumption data, Cui et al. (2021) estimate that the policies caused a 16.7% reduction in total emissions and a 9.7% reduction in emission intensity. Based on industry-level data, Hu et al. (2020) find that energy consumption in the pilot ETS regions fell by 22.8% and carbon emissions by 15.5% compared to non-regulated regions. These are sizable effects which came at a cost. Cui et al. (2021) find that regulated firms achieved emission reductions by compromising employment and capital inputs. Cao et al. (2021) show that firms in the regulated electricity sector reduced coal consumption at the cost of output contraction. Based on similar data, Cui et al. (2023) estimate that the pilot ETS caused a 9% increase in carbon emissions at unregulated companies that share ownership networks with ETS-related firms, which suggests that there is carbon leakage within firms.

Further research on China's pilot ETS has examined outcomes beyond carbon emissions. Almond & Zhang (2021) estimate that areas regulated by the pilot programs experienced a 7.6 percent increase in visibility compared to unregulated areas, indicating improvements in local air quality. Additional evidence points to an innovation response. Within regulated locations, Zhu et al. (2019) show that firms under a fixed, mass-based permit allocation conducted significantly more low-carbon innovation than those receiving free permits according to a rate-based permit allocation updating rule. Using firm-level patent data, Cui et al. (2018) find that there is faster development of low-carbon technologies among firms located in the pilot ETS regions compared to those in other regions after controlling for sector trends.

Our paper contributes to this literature by bringing, for the first time, information on management quality to bear on this. Since this information is not available from existing data sources, we have collected new data by conducting in-depth interviews with firm managers, using a well-established telephonic survey tool (Bloom & van Reenen, 2007). The data allow us to disentangle managerial decisions and attitudes from the firm's ex-post response to regulation. Compared to the literature cited above, our dataset has the further advantages that it is not limited to listed firms, and that ETS-regulated firms are identified directly rather than using proxies such as location or industry.

Much of the empirical research on carbon trading so far has been conducted in the context of the EU carbon market (see Martin et al., 2016, for a survey), and focused on identifying causal impacts (e.g., Calel & Dechezleprêtre, 2016, Colmer et al., 2022). Our analysis of the pilot ETS in China not only adds to that body of literature but also connects it to the new empirical management literature. This new link allows us to understand how management practices interact with cap-and-trade policies.

Our interest in the Chinese pilot ETS fits in with a rich emerging literature on the costs and benefits of regulating China's challenging environmental problems (Chang et al., 2018, 2019, Graff-Zivin et al., 2020, Ito & Zhang, 2020, Jin et al., 2017, Kahn et al., 2015). Recent research in this strand of literature has established the strong impact of pollution regulation on firm-level total factor productivity (He et al., 2020). Our paper sheds light on how management quality, a fundamental yet so-far unmeasured component of the productivity residual, interacts with regulation in the context of China's war on pollution.

Beyond this particular policy context, our paper contributes to the new empirical management literature which seeks to measure the contribution of management inputs to firm productivity (e.g., Ichniowski et al., 1997, Bertrand & Schoar, 2003, Bloom & van Reenen, 2007). Recent research in this area has focused on understanding this relationship for the particular case of developing countries (Bloom et al., 2013, McKenzie & Woodruff, 2017, Bloom et al., 2016). For China, Karplus et al. (2021a) have shown that general management practices are positively associated with productivity in state-owned firms but not in private firms. We contribute novel data on management practices at Chinese firms, focusing on management practices that relate to energy use and climate change mitigation. Our questionnaire is based –in large parts, but with appropriate modifications– on a Chinese translation of the one previously used in nearly one thousand interviews with firm managers in Belgium, France, Germany, Hungary, Poland, and the United Kingdom (Martin et al., 2012, 2014a, 2015).

3 Data and Summary Statistics

Our sample consists of 216 firms that were interviewed about their management practices in 2016 and 2017. The sampling frame included all firms in Beijing and Hubei from the ORBIS database of Bureau Van Dijk operating in sectors subject to the ETS and for which financial data was available. Out of these 5,707 firms, we over-sampled firms participating in the pilot ETS system, identified from official lists and matched to ORBIS based on their names. In total, we contacted 1,644 firms in the two regions. As shown in Appendix A.1, conditional on a firm's participation in the ETS, there is no evidence of selection on observable characteristics into our sample of firms contacted. This is also true ex-post of the sample of interviewed firms, as reported in Appendix Table A.1. This is reassuring given the low average response rates of 6% among ETS firms and 7.1% among non-ETS firms. As Table A.2 reports in more detail, response rates were substantially higher in Beijing than in Hubei. For all interviewed firms, we obtained additional information from two other datasets, namely patent filings from the China National Intellectual Property Administration database (CNIPA) and energy consuption from the Chinese State Administration of Tax (CSAT) dataset. The remainder of this section describes all data sources and the construction of the analysis sample in more detail.

3.1 Data Collection

The environmental performance of a firm is commonly reflected in a range of measurable outcomes, including pollution emissions, energy usage or ISO 14001 certification (Earnhart, 2018). However, these variables do not allow us to directly infer environmental management practices. We therefore ran a survey to elicit information on management practices related to climate change in general and to the pilot ETS in particular. Building on previous work by Martin et al. (2012, 2014b), we conducted structured interviews with managers based on a questionnaire successfully used in Europe.[3] The questionnaire covers aspects such as carbon trading, energy consumption, innovation, pollution and GHG emissions

[3] See in Appendix C.1 the survey questions in Chinese, with an English translation.

control, as well as general management practices. The questions concern practices and elements in place at the time of the interview.

The target respondent is a plant manager or lead engineer with knowledge about environmental issues in the firm. We conducted the survey via the telephone and followed a protocol pioneered by Bloom & van Reenen (2007) to minimize cognitive bias often present in conventional surveys. For example, managers' responses may be biased if interviewees tend to report socially desirable rather than actual practices. To avoid this, the use of open-ended questions followed by more detailed questions allows trained interviewers to better gauge management practices. Each question was evaluated on an ordinal scale from 1 to 5 with a higher score representing better performance. Potential cognitive bias on the part of interviewers and their way of inquiring are addressed by providing interviewers with benchmark examples for giving low, medium, and high scores. In addition, we double-scored a sub-sample of interviews.[4] Any remaining systematic bias can be controlled for in the regression analysis by use of interviewer fixed effects. Potential cognitive bias on the part of interviewees is addressed by controlling for age, tenure, educational background and gender.

Table 1 summarizes the variables in our sample. The first panel shows that, on average, managers of firms located in Beijing more likely to have a degree in business management (55% vs. 31%). Other manager characteristics are not significantly different between the two regions. Managers have been on average about 10 years at the firm, are about 40 years old and 20% of them are female. Firms in Beijing are on average about 6 years older than firms in Hubei. About 40% of the firms in the sample are state-owned and 47% engage in export activities. Table A.5 further compares ETS with non-ETS firms within each region: ETS firms tend to have managers that have been at the company for about 2.5 extra years but 1.5 years less in their actual role. ETS firms are larger in terms of employment, turnover, and capital. They are also more likely to be state-owned.

[4] See the results of the double-scoring in Appendix A.1

Table 1: Summary Statistics and Sample Characteristics

	Beijing	Hubei		All Firms			
	Mean	Mean	p-value	Mean	S.D.	Obs.	N
Interview characteristics data							
Manager's tenure in company in years	9.95	9.48	0.736	9.88	7.15	206	206
Manager's tenure in position in years	6.18	5.26	0.349	6.04	5.08	206	206
Manager's education in business management	0.55	0.31	0.013	0.51	0.50	210	210
Manager is female	0.19	0.18	0.957	0.19	0.39	216	216
Manager's age in years	38.74	40.94	0.167	39.10	8.33	201	201
Firm's age in years	20.86	14.82	0.000	19.94	7.73	216	216
Firm is state-owned	0.42	0.30	0.227	0.40	0.49	216	216
Firm engages in export	0.49	0.33	0.179	0.47	0.50	149	149
Management index							
CCM index	-0.04	0.20	0.012	0.00	0.50	216	216
Carbon market indices							
Participant in pilot ETS market	0.44	0.58	0.143	0.46	0.50	216	216
Rationality of current trading score	1.79	1.64	0.609	1.77	0.99	83	83
Stringency of current pilot ETS index	-0.17	0.26	0.037	-0.10	0.80	119	119
Anticipated stringency of future ETS index	-0.18	0.16	0.009	-0.13	0.68	216	216
Green Innovation							
Process innovation score	1.68	1.81	0.471	1.70	0.96	216	216
Product innovation score	1.92	2.12	0.357	1.95	1.16	216	216
Innovation index	1.80	1.96	0.320	1.82	0.89	216	216
Firm has green patents	0.46	0.40	0.719	0.45	0.50	64	64
Share of green patents	0.11	0.03	0.219	0.10	0.19	64	64
ORBIS data							
Turnover in 000's USD	162,439	78,082	0.098	152,565	650,552	1,572	216
Employment	1,326	690	0.078	1,241	3,481	804	206
Capital in 000's USDs	117,061	64,914	0.106	110,997	409,449	1,565	216
Cost of goods sold in 000's USDs	122,814	69,454	0.206	116,611	521,126	1,488	216
Firm energy							
Oil usage in 000's tons	1,172	1,791	0.598	1,243	11,471	942	181
Coal usage in 000's tons of oil equivalent	17,381	164,294	0.000	34,207	217,723	943	181
Electricity usage in megawatts	2,283	9,206	0.007	3,075	25,076	943	181
Oil intensity in tons of oil per million USD	52	99	0.409	57	556	943	181
Coal intensity in tons of coal per million USD	313	1,103	0.000	404	2,053	943	181
Electricity intensity in megawatts per million USD	94	98	0.983	94	1,834	943	181

Notes: The p-value refers to the t-test for equality of means between firms in Beijing City and Hubei Province. *S.D.* stands for standard deviation, *Obs.* for observations and N is number of firms.

3.2 The Climate Change Management Index

Based on the answers to the core set of interview questions, we construct a summary measure that we refer to as the Climate Change Management Index (CCM index for short). It is computed as the average of 21 normalized z-scores[5] that measure different aspects of management related to climate change: awareness of issues of climate change and pollution; energy and GHG emissions monitoring, targets and enforcement; competitive and customer pressure on climate change issues. The components of the index are described in full detail in Table A.4. By construction, the CCM index has a sample average of zero, but it is significantly higher for ETS firms (0.24) compared to non-ETS firms (-0.21), and for the average firm in Hubei (0.20) than in Beijing (-0.04). The difference is significant at the 1% and 5% confidence level, respectively.[6] Figure 1 displays the distribution of the CCM index. The distribution is skewed to the right because a few firms scored high on all of the management practices that were discussed in the interviews.[7] The distribution of the components is illustrated in Figure A.2.

3.3 Firm Behavior on the Carbon Market

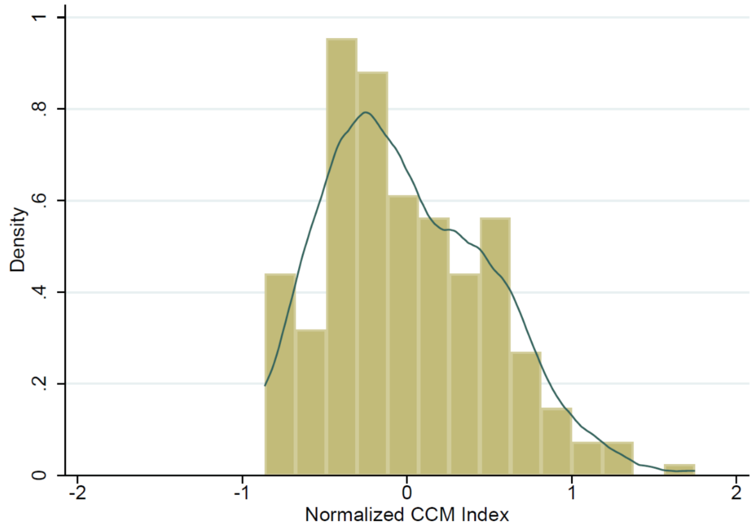
As a result of our sampling approach, about half of the firms in our sample participate in a pilot ETS (44% in Beijing, 58% in Hubei). In addition to the abovementioned z-scores, our questionnaire included questions that help us understand how firms behave on the carbon market. First, the *rationality-of-trading score* is based on the interviewee's responses to questions about how firms decide to sell and buy permits, whether they base these decision on forecasts about prices and/or energy usage, and whether they trade off permit revenue against emission reductions costs (see question VI of the survey in Appendix C.1). A low score is

[5]The z-scores are computed by subtracting from the raw score the average score and dividing by the standard deviation

[6]Of the 183 Beijing firms in our sample, 80 firms participated in the Beijing pilot. 68 of them participated since 2014 (early ETS firms), and the remaining 12 participated since 2016 (late ETS firms). We fail to reject the hypothesis of equal average CCM index between early and late ETS firms ($p = 0.485$).

[7]The Beijing Environmental Exchange Company offered training programs related to carbon trading policies to both regulated and non-regulated firms. It would be interesting to analyze the correlation between participation in such training programs and our CCM index. Unfortunately, information about which firms participated is not available.

Figure 1: Distribution of the Climate Change Management Index



Notes: Histogram and kernel density of CCMI. Full sample (216 firms).

assigned to firms that do not take into account the price of permits or the cost of abatement, while a high score is given to firms that have a thorough understanding of their CO_2 abatement cost curve. Firms in Beijing and Hubei did not significantly differ in their market behavior. The average score of 1.77 suggests a relatively passive attitude towards the management of permits. This is consistent with very low trading volumes on the markets discussed in the literature.

Second, the *market stringency index* measures how difficult it is for the firm to make do with the emissions permits granted to its production site, how strict the enforcement by the authorities has been, and how large their estimation of the cost burden of being part of the pilot ETS as a share of annual operating cost is (survey question VII).

Third, the *anticipated stringency of future ETS index* captures, for firms expecting to be part of the nation-wide ETS, how stringent they expect the next phase to be, whether sanctions will be imposed for non-compliance, whether auctioning will be used to allocate allowances, and whether they deem it likely that the nation-wide carbon market will actually be launched (survey question VIII).

3.4 Innovation

Green innovation is captured by both an index relying on the management questionnaire and actual patent data. Our survey data focused on the innovative effort (rather than outcome) distinguishing between process and product innovation. Process innovation is the use of new methods or new technologies to reduce energy use or GHG emissions in the production of existing products (survey question IX). Product innovation refers to the invention of products that allow users to reduce their emissions footprint (survey question X). To measure how firms perform in terms of their innovative efforts we included questions such as whether their company dedicates staff time and financial resources to finding innovative ways of reducing GHG emissions at their production facility, or to producing greener products, and prompted them for examples. Process and product innovation scores are not significantly different between the two regions. The average process and product innovation score are, respectively, 1.70 and 1.95, meaning that the amount of R&D resources committed to these purposes was not large. We combine process and product innovation scores into an overall *innovation index*. Because ETS firms score higher in terms of process innovation (1.96) compared to non-ETS firms (1.48), their overall innovation index (1.98) is slightly higher than that of non-ETS firms (1.69).

Further information on innovation is obtained from the CNIPA database, which covers all the published patent applications from 1985 in China and contains detailed information on each patent. We use the number of approved patents as an objective measure of a firm's innovation efforts. Moreover, we classify a patent as green if its International Patent Classification code (IPC code) coincides with the IPC Green Inventory code that was developed by the IPC Committee of Experts in the World Intellectual Property Organization. We use the number of approved green patents to measure firms' innovation in green technologies and compute the share of green patents as a percentage of the total number of patents. 40% of firms that innovate in Hubei vs. 46% of firms that innovate in Beijing have at least one green patent, and this difference is not statistically significant. Among the 61 firms that hold patents in our sample, one out of ten patents is classified as green in the above-defined sense. We cannot reject the hypotheses that, on average, ETS firms have different holdings of patents or green patents (10% significance or better).

3.5 Financial Data

The ORBIS dataset provides firm-level financial data in US dollars. We extract data for the period from 2007 until 2015 on the annual turnover, capital (measured as fixed assets), employment, and cost of goods sold (COGS) which summarizes the cost of labor and materials used to produce output. These measures allow us to account for differences in size and inputs and to assess the annual changes in energy intensity per turnover. As reported in Table 1, turnover and employment are twice as large in Beijing firms as in Hubei firms; the differences are statistically significant at the 10% level. Capital and COGS are also larger in Beijing but the differences lack statistical significance. ETS firms are several times larger than non-ETS firms for all the ORBIS variables.

3.6 Energy Consumption

Chinese State Administration of Tax (CSAT) data were obtained for the years 2008 to 2014 for 173 of the firms we interviewed in Beijing city and Hubei province. This dataset provides us with firm-level consumption of oil, coal and electricity, but not natural gas.[8] We perform several quality checks on the energy data to rule out the possibility that the occurrence of missing or zero consumption values in the raw data is systematically correlated with firm characteristics, ETS status, or climate-centric management practices.[9] For each fuel, we compute energy intensity by

[8] Natural gas accounted for less than 6 percent of total energy consumption and less than 5 percent of energy consumption in manufacturing before 2015, cf. Chinese Statistical Yearbooks http://www.stats.gov.cn/sj/ndsj/2017/indexeh.htm, last accessed July 6, 2023.

[9] Table A.6 displays the number of firms that report zero consumption of each fuel in each year. Table A.7 presents results from a regression-based test of whether energy data availability varies systematically with firm characteristics, with management quality, or between ETS and non-ETS firms. We define three different indicators of data quality, separately for coal, oil and electricity: (i) the number of years with non-missing fuel data, (ii) the numbers of years with fuel values equal to zero, and (iii) whether a firm was reporting in the CSAT dataset. For each fuel, we regress these indicators on the firms' regulatory status, location, employment, capital, turnover, state ownership, firm age and management. The only statistically significant association we find is that Hubei firms are less likely to have missing values. None of the other characteristics predicts data availability.

taking the ratio of oil (in tons of oil equivalent), coal (in tons of coal equivalent) and electricity consumption (in megawatt hours), divided by the firm's turnover (in million USD).

Average coal intensity is higher in Hubei than in Beijing. Apart from reflecting differences in the industry structure, this could be the result of higher participation thresholds that prevailed in the Hubei pilot. Table A.8 shows that the regional difference is less pronounced for non-ETS firms. Generally, ETS firms have higher energy usage and intensities than non-ETS firms.

4 Climate Change Management and Firm Performance

This section provides evidence on how climate-centric management, measured by the CCM index, is correlated with productivity, energy efficiency, and innovation.

4.1 Productivity

To analyze the management-productivity nexus, we regress the log turnover (y) of firm i in year t on firm i's CCM index ($CCMI_i$) and further controls:

$$y_{it} = \alpha_0 + \beta_M CCMI_i + \mu' c_{it} + x'_{it}\gamma + z'_i\delta + u_{it}. \tag{1}$$

The vector c_{it} contains (the log of) employment, capital, and cost of goods sold. Controlling for c_{it} allows us to interpret the coefficient on $CCMI_i$ as the effect on the productivity residual. The CCM index captures management practices in place in 2016-2017, at the time of the interviews, whereas t runs from 2007 to 2015. Our approach rests on the assumption that management practices only change gradually over time due to factors such as ownership structure, preferences of senior management staff, slow diffusion of knowledge and high adjustment costs (Bloom & van Reenen, 2007). The vectors x_{it} and z_i control for firm and interview characteristics, respectively. In all regressions throughout this section, we use two sets of control variables. *Firm-level controls* include age, as well as dummies for exporter status, state-owned entreprise, region and industry at the two-digit NACE

Table 2: Climate Change Management and Productivity

	Log Turnover		
	(1)	(2)	(3)
CCM index	0.924***	0.709***	0.150**
	(0.203)	(0.177)	(0.063)
Hubei firm		-0.088	-0.009
		(0.226)	(0.081)
State-owned		0.479***	0.069
		(0.159)	(0.061)
Log(Employment)		0.482***	0.064
		(0.092)	(0.050)
Log(Capital)			0.153***
			(0.038)
Log(Cost of Goods Sold)			0.729***
			(0.072)
Number of observations	1,572	1,572	1,572
Number of firms	216	216	216
R^2	0.462	0.599	0.896
Adjusted R^2	0.444	0.583	0.891

Notes: Pooled OLS regressions of the log turnover between 2007 and 2015 on CCM index and various firm attributes. All regressions control for year, industry, interview noise controls (the day-of-week of the interview day, the interviewer fixed effects as well as tenure, educational background, and gender of the manager interviewed). In addition to the explanatory variables reported, columns (2) and (3) also control for exporter status, firm age in logs. Robust standard errors in parenthesis are clustered at the firm level. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

level.[10] *Interview 'noise' controls* include the day-of-week on which the interview took place, interviewer fixed effects as well as characteristics of the manager interviewed such as tenure, educational background and gender. The stochastic error term u_{it} is clustered at the firm level.

Table 2 reports the OLS parameter estimates of eq. (1). In all specifications, the CCM index is positively and significantly associated with (log) turnover. The coefficient estimate drops from 0.924 in column (1) to 0.709 when firm characteristics are included in column (2). This suggests that better managed firms also have

[10]NACE is the acronym for "Nomenclature statistique des activités économiques dans la Communauté europeenne".

higher returns to production and sales. In column (3), the association remains positive and statistically significant, but the coefficient further drops to 0.150. The coefficient implies that a one-standard-deviation increase (0.50) in the CCM index is associated with a 7.8% increase in revenue productivity.[11]

This result is consistent with the earlier finding that higher productivity is associated with better general management practices[12] and closely mirrors a result obtained for UK manufacturing firms (Martin et al., 2012). Given the similarity of the research design, it is possible to meaningfully compare the effect magnitudes implied by the parameter estimates in our sample and in Martin et al. (2012, cf. Table 2 column 2) which are 0.150 and 0.119, respectively. Increasing the CCM index by one standard deviation is associated with a 5% increase in revenue productivity among UK firms vs. 7.8% at Chinese firms.[13] Further results presented in Appendix B.2 suggest that the positive association of the CCMI and revenue productivity is mainly driven by monitoring of energy use and GHG emissions.

4.2 Fuel Intensity

One channel for management practices to enhance productivity is by improving the efficiency of energy use. In line with this, a negative correlation between the World Management Index (WMS) that measures general management practices, and energy intensity was documented for manufacturing firms in the UK (Bloom et al., 2010), but not in the U.S. (Boyd & Curtis, 2014). For UK firms, Martin et al. (2012) show that management practices related to climate change are negatively correlated with energy intensity, measured as energy costs in variable costs. We lack information on energy costs, but we can investigate whether *physical* energy intensity measures correlate with climate-friendly management by using the ratio of fuel use and turnover as the dependent variable in eq. (1). We obtain positive

[11] $e^{0.5*0.150} - 1 = 7.8\%$.

[12] Bloom et al. (2013) estimate the causal impact of adopting good management practices on productivity in the textile industry in India, an emerging economy sometimes compared to China. They find that increasing the general management score by one standard deviation causes a 17% increase in productivity.

[13] Based on specification (3); one standard deviation of the CCM index obtained by Martin et al. (2012) is 0.41. A two-sample t-test does not allow us to reject the Null hypothesis of no difference between the coefficients.

yet statistically insignificant coefficient estimates on the CCM index for all fuels (Table B.1).[14] Similarly, Grover & Karplus (2020) found physical measures of energy intensity and energy-centric management practices to be positively correlated in survey data from the World Bank Enterprise Survey. They cite selective adoption by energy-intensive firms as a likely driver of a spurious positive correlation between the two variables.[15][16] In Section 5, we shall revisit energy consumption as an outcome variable when analyzing how management practices interact with policies aimed at reducing carbon emissions.

4.3 Green Innovation

Since 2006, the Chinese government has enforced increasingly ambitious and wide-ranging environmental policies in successive Five Year Plans (Karplus et al., 2021b). Over the same time period, patenting in green technologies has increased substantially (Linster & Yang, 2018). In line with the notion that regulation can spur the development of green technologies, Cui et al. (2018) show that low-carbon patents applied for by stock-market listed firms in the ETS regulated sectors and located in the ETS pilot regions increased by 19% between the announcement of ETS in 2011 to 2015. This change is measured relative to a control group of firms in the same sectors but located outside pilot regions. Similarly, Zhu et al. (2019) find that ETS firms on average filed 1.75 more low-carbon patents relative to their non-ETS counterparts during the first two years of China's pilot ETS.

Our survey data allow us not only to analyze how well the firms in our sample perform on the green innovation front, but also to assess how well patent data, used in previous work, proxies for otherwise unobserved green innovation efforts captured by our survey. To this end, we regress patents and green patents measures on innovation scores while controlling, as above, for a range of firm characteristics and interview noise in Table 3. Each cell refers to a separate re-

[14]We also report coefficients for individual of CCMI components in Appendix B.2.

[15]Moreover, physical energy-intensity measures differ from cost-based energy intensity in this pooled regression because of variation in fuel prices across firms and regions. Managers might focus on reducing energy cost and not physical energy use. We thank an anonymous referee for this suggestion.

[16]A promising way of breaking such a possible correlation is to randomly assign information on energy related management practices, cf. Karplus & Zhang (2022).

Table 3: Green Patents and Innovation Practices

	Any patent [Yes=1]	Any green patent [Yes=1]		Green patents [0-400]	Green patent share [0-1]
	(1)	(2)	(3)	(4)	(5)
CCMI index	0.000	0.074	0.408**	1.628*	0.127**
	(0.068)	(0.055)	(0.171)	(0.859)	(0.045)
Innovation index	-0.058	0.013	0.201*	-0.017	0.069*
	(0.039)	(0.030)	(0.100)	(0.516)	(0.035)
Process innovation score	-0.047	0.010	0.218**	0.882	0.066**
	(0.037)	(0.027)	(0.079)	(0.766)	(0.029)
Product innovation score	-0.034	0.008	0.075	-0.273	0.030
	(0.032)	(0.025)	(0.084)	(0.286)	(0.026)
Regression	OLS	OLS	OLS	NB	OLS
Number of firms	216	216	61	61	61

Notes: Each cell represents separate OLS or negative binomial (NB) regressions. The full sample is comprised of 216 firms and includes those that do not hold any patent. The dependent variables are: a binary variable equal to one if the firm reports at least one patent and zero otherwise (column 1), a binary variable equal to one if the firm reports at least one green patent and zero otherwise (columns 2 and 3), the number of green patents (column 4), and the share of green patents in total patents (column 5). Columns 3 to 5 condition on the 61 firms that report at least one patent. Each regression includes *firm-level controls* and *interview 'noise' controls*. In analogy to the productivity analysis, the regressions also control for employment and cost of goods (in log averages between 2007 and 2015). Robust standard errors in parenthesis. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

gression, with survey-based measures of green innovation varying across rows and patent-based innovation measures across columns. The first two columns report extensive-margin innovation responses obtained by estimating linear probability models on the full sample (216 firms). The coefficients measure the associations between the CCM index, the innovation index, the process innovation and product innovation scores, and the propensity to hold any patent (column 1) or any green patent (column 2). For the intensive margin, we restrict the sample columns (3)-(5) to the 61 firms that have at least one patent. Column (3) analyzes the propensity to file green patent applications and column (4) the number of green patents which ranges from zero to 400. Thirteen out of the 61 innovating firms report between one and 33 green patents, and one firm reports 400 (the distributions are plotted in Figure A.3). To reduce the disproportionate effects of large patent holders on the results, column (5) reports coefficients on the share of green patents in the total number of patents.

Three patterns emerge from these regressions. First, firms with better climate-friendly management practices or innovation scores are not more likely to hold patents or green patents. That is, at the extensive margin, greener management is not a predictor of innovation. Second, among firms that successfully engage in R&D (proxied by owning at least one patent), climate friendly management practices are positively associated with the propensity to hold green patents as well as with absolute and relative patent counts. This robust association is not mechanical because the CCM index does not contain any of the specific z-scores on innovation. Third, firms engaging in climate-friendly process innovation are significantly more likely to hold green patents as well as a higher share of green patents. No statistically significant such association is found among firms that innovate in climate-friendly products.

5 Management Practices and Carbon Trading

This section analyzes how climate change related management practices interact with firm-level responses to climate change policies. As a case-in-point, we study firm-level adjustments to energy usage following the introduction of the Chinese pilot emissions trading schemes. We are interested in how these adjustments differ between well-managed firms and the rest of the pack. Our empirical analysis focuses on the period from 2008 to 2014 for which energy consumption data are available (see Section 3.6). Only firms reporting non-zero fuel consumption in at least one year are included.

5.1 Changes in Fuel Use in Response to Carbon Trading

To estimate the impact of the ETS on energy use, we measure how regulated firms change their energy use following the introduction of the ETS and compare it to unregulated firms. To accommodate the fact that some firms never use certain fuels, we assume that firm i's fuel demand e_{it} is given by

$$e_{it} = \theta_i f(x_{it}, \epsilon_{it}) \geq 0 \tag{2}$$

where θ_i is a fixed effect and f a non-negative function of observable covariates x_{it} and a random disturbance ϵ_{it}. A simple Differences-in-Differences (DiD) estimator for this model is obtained by averaging energy use in pre- (e_i^{pre}) and post-treatment periods (e_i^{post}) and calculating the midpoint growth rate as

$$\gamma_i = \frac{e_i^{post} - e_i^{pre}}{0.5 \times (e_i^{post} + e_i^{pre})}. \tag{3}$$

This statistic is well-suited to our application because it accommodates zero energy consumption and because unobserved heterogeneity θ_i drops out.[17] We take e_i to be physical fuel input, i.e. coal or oil usage in tons, or electricity usage in 10,000 Watts. As an alternative outcome variable, we compute the fuel intensity as fuel input over turnover (in 1,000 USD) and calculate its growth rate as in eq. (3).

In our sample, we can compute these growth rates for 152 firms, 72 of which are regulated by the ETS and 77 of which are well managed (above the median of the CCM index). Table A.9 cross-tabulates ETS status, CCM index, and energy consumption before the introduction of the ETS in 2013. ETS-regulated firms and big energy consumers tend to be better managed: of the 77 well-managed firms only 21 are not ETS-regulated. The average consumption of coal and electricity

[17] Below we also explore the robustness to using a Poisson specification which is an alternative way to deal with zero values and unobserved heterogeneity.

Table 4: ETS Impact on Energy Use

Dependent variables:	ΔCoal		ΔOil		ΔElectricity	
	(1)	(2)	(3)	(4)	(5)	(6)
A. Growth in Fuel Use						
ETS firm	-0.304	0.724	-0.301	-0.354	-0.238	0.249
	(0.277)	(0.460)	(0.209)	(0.369)	(0.206)	(0.383)
Above-median CCM index		0.375		-0.120		0.334
		(0.470)		(0.293)		(0.331)
×ETS firm		-1.499**		0.146		-0.848
		(0.640)		(0.482)		(0.514)
Number of firms	108	108	145	145	152	152
R^2	0.011	0.065	0.015	0.016	0.009	0.030
Adjusted R^2	0.002	0.038	0.008	-0.005	0.002	0.010
B. Growth in Fuel Intensity						
ETS firm	-0.362	0.556	-0.225	-0.268	-0.206	0.277
	(0.284)	(0.476)	(0.210)	(0.370)	(0.200)	(0.382)
Above-median CCM index		0.221		-0.069		0.151
		(0.501)		(0.296)		(0.321)
×ETS firm		-1.261*		0.101		-0.720
		(0.669)		(0.484)		(0.503)
Number of firms	108	108	145	145	152	152
R^2	0.015	0.057	0.008	0.008	0.007	0.026
Adjusted R^2	0.006	0.029	0.001	-0.013	0.000	0.006

Notes: OLS regressions include a constant (not reported). The dependent variables are the midpoint growth rates, as defined in eq. (3), of fuel inputs (Panel A) and of fuel inputs divided by turnover (Panel B). Coal and oil inputs are measured in tonnes, electricity input in 10,000 Watts, and turnover in million USD. Robust standard-errors in parentheses. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

is an order of magnitude larger among well-managed firms than among the rest of the pack.

We estimate regressions of the form

$$\gamma_i = \alpha + \mathbf{D}_i \beta + \varepsilon_i \tag{4}$$

where γ_i is the growth rate in fuel consumption or fuel intensity and $\mathbf{D}_i$ is a vector of dummy variables that partitions the sample into different groups of firms. Table 4 reports a set of results where firms are distinguished by ETS status and climate-centric management. Defining good management as being above the median CCM index, we have:

$$\mathbf{D}_i = [ETSFirm_i, AboveMedianCCM, ETSFirm_i \times AboveMedianCCM_i]. \tag{5}$$

Our main results, reported in Table 4, are summarized as follows. First, the regressions without interaction terms (in odd-numbered columns) reveal that ETS participation reduced both growth in fuel consumption (Panel A) and growth in fuel intensity (Panel B) for all fuels. However, since none of these point estimates are statistically significant at conventional levels, we cannot reject the hypothesis that emissions trading had no effect on energy conservation. Second, when distinguishing treatment effects between well-managed and not-so-well managed firms (in even-numbered columns), we find that the ETS caused regulated firms with above-median values on the CCM index to curb coal consumption relative to unregulated firms. This effect is not only statistically but also economically significant, as shown in Section 6 below. Third, we find no significant evidence of substitution towards oil or electricity for those firms. Fourth, the reduction in coal use, which could in principle be driven by output changes, mainly arises from a reduction in the intensity of coal use relative to turnover, which is somewhat less precisely estimated ($p = 0.062$) in Panel B.

Collectively, these findings suggest that, on average, the ETS as policy instrument unfolded its carbon-saving potential only among those firms that had adopted climate-friendly management practices. This has important policy implications which we shall further discuss in Section 6 below.

5.2 Robustness

5.2.1 Management practices vs. firm-level confounders

Our results indicate that well-managed firms respond more strongly to carbon pricing than not-so-well managed firms. To support the notion that climate-change related management practices are the main driver of post-treatment energy changes, we analyze and evaluate the possibility that omitted correlates of management are driving this. For example, the fact that better managed firms also use more energy - in particular coal - raises concerns that we might be picking up the effect of size rather than that of management. Large firms may be better managed than small firms, but they might also be in a better position to reduce energy consumption in response to regulation for reasons unrelated to management. Table A.3 reports raw correlations between the CCM index and firm characteristics, showing that employment, capital, turnover, coal use, electricity use, ETS participation and Hubei location are all positively correlated with good management.

We test for confounding effects of those variables by directly controlling for them in an augmented regression of eq. (4). Analogous to our treatment of the CCM index, we include binary controls for each characteristic as well as their interactions with ETS participation. The coefficients on those interaction terms measure the differential response of ETS firms that, prior to treatment, were in the top half of the distribution of the respective firm characteristic. Results reported in Table 5 show the influence of the CCMI, employment, consumption of the fuel considered, labor intensity, turnover, capital, and age, when interacted with the ETS dummy. Following Karplus et al. (2021a), we also allow for differential responses of state-owned enterprises (SOE).

The coefficients of interest on $ETSFirm_i \times AboveMedianCCM_i$ for coal are very similar to the parsimonious specification in Table 4, albeit somewhat larger, raising the statistical significance in the intensity regression to the 5% level.[18] The corresponding coefficient estimates for oil in columns 2 and 4 and electricity in columns 3 and 6 remain statistically insignificant. Above-median users of coal and oil reduce their consumption by more than firms below the median, all else equal. The sign of the coefficient on ETS participation in the electricity growth regressions is sensitive to the initial level of electricity use. The other ETS interaction terms lack statistical significance at conventional levels. In sum, the results of the more demanding specifications support the notion that ETS-regulated firms reduced their coal consumption only when their level of climate-friendly management was above the median.[19]

[18] Note that a reduction of 100% in "midpoint" growth terms corresponds to a 60% reduction in the standard growth rate.

[19] General management practices could be a confounder of energy-centric management practices (Grover & Karplus, 2020). Unfortunately, the overlap between our sample and WMS data is too small (N=2) to control for general management practices separately. However, our detailed questionnaire with questions specifically addressing energy and climate-related aspects of management should minimize the risk of mistaking general management practices for climate-centric management practices. Results on individual management practices presented in Section 6 corroborate that we indeed measured dimensions of management quality pertinent to our research question.

Table 5: ETS Impact on Growth of Energy Use and Intensity with Controls

Dependent variables:	Growth in Fuel Use			Growth in Fuel Intensity		
	ΔCoal	ΔOil	ΔElectricity	ΔCoal	ΔOil	ΔElectricity
	(1)	(2)	(3)	(4)	(5)	(6)
ETS firm	0.598	0.002	0.903*	0.414	0.062	1.126**
	(0.858)	(0.618)	(0.525)	(0.857)	(0.644)	(0.556)
Above-median CCM index	0.511	-0.023	0.193	0.367	0.265	0.008
	(0.420)	(0.321)	(0.345)	(0.450)	(0.286)	(0.326)
× ETS Firm	-1.539**	-0.015	-0.514	-1.327**	-0.238	-0.564
	(0.643)	(0.504)	(0.481)	(0.648)	(0.476)	(0.502)
Above-median fuel consumer	-0.827*	-0.808***	-0.298	-0.812	-1.288***	0.035
	(0.439)	(0.286)	(0.401)	(0.507)	(0.318)	(0.306)
× ETS Firm	0.244	-0.268	-1.360**	-0.087	0.398	-0.939*
	(0.659)	(0.487)	(0.602)	(0.665)	(0.465)	(0.481)
Above-median employment	0.463	0.474	-0.857**	0.205	0.271	-0.858**
	(0.618)	(0.358)	(0.341)	(0.658)	(0.338)	(0.341)
× ETS Firm	-0.930	-0.351	0.255	-0.587	-0.030	0.636
	(0.687)	(0.550)	(0.475)	(0.714)	(0.501)	(0.457)
Above-median labor intensity	0.031	-0.087	0.512	0.112	-0.055	0.440
	(0.447)	(0.317)	(0.315)	(0.518)	(0.293)	(0.327)
× ETS Firm	-0.323	-0.492	-0.322	-0.384	-0.506	-0.431
	(0.595)	(0.484)	(0.436)	(0.645)	(0.467)	(0.427)
Above-median turnover	-0.223	-0.015	0.977**	-0.349	-0.543	0.971***
	(0.669)	(0.367)	(0.393)	(0.675)	(0.347)	(0.357)
× ETS Firm	1.329	0.297	0.327	1.372	0.188	-0.513
	(0.895)	(0.615)	(0.623)	(0.876)	(0.592)	(0.547)
Above-median capital	0.602	-0.150	0.175	0.756	0.065	0.104
	(0.575)	(0.326)	(0.366)	(0.574)	(0.282)	(0.317)
× ETS Firm	-0.564	0.105	0.106	-0.695	-0.073	-0.097
	(0.725)	(0.484)	(0.574)	(0.718)	(0.461)	(0.554)
Above-median age	0.219	-0.012	0.014	-0.037	0.164	-0.026
	(0.425)	(0.275)	(0.290)	(0.468)	(0.287)	(0.272)
× ETS Firm	0.405	0.073	-0.398	0.679	-0.461	-0.514
	(0.580)	(0.460)	(0.420)	(0.597)	(0.473)	(0.414)
State-owned enterprise	0.430	0.314	0.054	0.574	0.166	0.084
	(0.508)	(0.337)	(0.294)	(0.539)	(0.348)	(0.306)
× ETS Firm	-0.652	0.072	-0.007	-0.759	0.138	0.055
	(0.638)	(0.461)	(0.406)	(0.657)	(0.475)	(0.421)
Number of firms	108	145	152	108	145	152
Adjusted R^2	0.061	0.079	0.139	0.078	0.143	0.055

Notes: OLS regressions include a constant (not reported). The dependent variables are the midpoint growth rates as defined in eq. 3 for tons of coal (columns (1) and (2)), tons of oil (columns (3) and (4)), electricity (in 10,000 Watts) (columns (5) and (6)). SOE stands for state-owned enterprise. Above-median are dummies indicating the firm is above the sample's median for the CCM Index, or for their pre-2013 average energy consumption for each fuel, or for capital. Robust standard-errors in parentheses. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

5.2.2 Changes in management practices

Given that we elicited CCM practices three years after the launch of the ETS, an important identifying assumption is that practices were stable over this period. Violations of this assumption could lead to different biases in the estimation of the coefficient on $ETSFirm \times AboveMedianCCM$. If within-firm variability in management practices is unrelated to fuel use, classical measurement error in the CCM index would lead to attenuation bias. If, in contrast, post-ETS management practices reflected how strongly the firm adjusted its fuel use due to the ETS, this would generate a causality running from the ETS response to the CCM index. The latter type of endogeneity is of particular concern, as it would prevent us from learning how climate-friendly management moderates the effect of cap-and-trade.

In gauging the practical extent of these potential issues, it is important to remember that we use a binary variable of management quality in the regressions. This means that rank changes *within* the top or bottom halves of the distribution of the CCM index following the introduction of the ETS do not affect the regression. The concerns about changes near the median and, in particular, about radical management changes remain, however, as they likely change a firms' value of the $AboveMedianCCM$ dummy. Unfortunately, we lack information on pre-ETS management practices that would allow us to test for such changes.

However, a testable implication of a radical shift in any aspect of management is the hiring of a new manager in charge of those aspects. Since we interviewed the manager in charge of climate change and environmental aspects, we use information on the tenure of the manager to implement such a test. Specifically, we construct a dummy variable equal to one if the respondent's tenure in the current post had changed over the previous five years, which included the start of the ETS. We regress this variable on ETS participation, above-median CCM index, the interaction of the two, and on controls for sector and interview noise. Based on the results reported in Table B.3 we cannot reject the hypothesis that manager changes were equally likely to occur at ETS vs. non-ETS firms, or at well-managed ETS firms vs. not well-managed ETS firms. This is robust to the inclusion of possible confounders related to size, energy use, or firm ownership. This result supports our identifying assumption, at least when it comes to radical pre-to-post changes in climate-related management practices within firms.

5.2.3 Policy confounders

While the above discussion has focused on the management component of the interaction term that identifies the coefficient of interest, we now discuss threats to the identification of the policy impact itself. In this differences-in-differences design, the estimated ETS impact might be biased due to overlapping environmental policies such as the National Air Quality Action Plan (NAQAP),[20] which has helped to drastically reduce population-weighted mean concentrations of $PM_{2.5}$ by an estimated 32% between 2013 and 2017 (Zhang et al., 2019). Thus, a potential concern is that those regulations were driving our key result. Since the NAQAP regulations applied to the entire Beijing-Tianjin-Hebei region (Ministry of Environmental Protection et al., 2012, The people's government of Hubei Province, 2014), the control group helps to net out their impact on the outcomes from our estimated treatment effects. Given their great ambition and stringency, the identifying assumption that NAQAP did not affect ETS firms in fundamentally different ways than non-ETS firms deserves further discussion. The same goes for the assumption that NAQAP regulations were unlikely to affect ETS firms in ways that are systematically related to their climate-related management practices.

First, given the large contributions of electricity generation and transportation to $PM_{2.5}$ pollution, those sectors were the primary targets of NAQAP regulations, whereas our sample consists mostly of manufacturing firms. Regression results reported in Table B.4 show that our results hold up when electricity firms are dropped from the estimation sample.

Second, within energy-intensive manufacturing sectors such as cement, iron and steel, and flat glass, air pollution control actions emphasized desulfurization and denitrification as the most effective way of abating $PM_{2.5}$ precursor emissions. Since end-of-pipe pollution control technology was available for those pollutants, firms were not forced to use less coal in order to comply with NAQAP. Moreover,

[20] See State Council of the People's Republic of China (2013). The principal measures under NAQAP were to strengthen industrial emission standards, to phase out small and polluting factories, to phase out outdated industrial capacities, to upgrade industrial boilers, to promote clean fuels in the residential sector, and to strengthen vehicle emission standards (Zhang et al., 2019).

if reducing fossil fuel use was the main strategy to comply with NAQAP, we would expect to estimate similar reductions in oil consumption. We do not find any reductions in oil consumption among well-managed firms, however.

Third, the mandatory phase-out of small coal-fired industrial boilers with a capacity of less than 7 MW (Zhang et al., 2019) likely reduced coal use. Because of its focus on small boilers, this NAQAP regulation strategy mainly affected firms in the control group, meaning that any bias in the estimated ETS effect on coal consumption would be towards zero.[21] It is therefore unlikely to drive our estimated treatment effect. In addition, there is no obvious reason for why the phase-out should differentially affect well-managed firms.

Fourth, NAQAP also phased out industrial excess capacity with high PM emissions. To the extent that this was achieved via firm closures, it does not affect our regression results, which are estimated on the balanced sample of firms we interviewed in 2016. However, capacity reductions could be influential if they occurred at the sub-firm level. The cement sector was subject to the largest capacity reduction under NAQAP (250m tons between 2013 and 2017). Results reported in Table B.4 show that our results are robust to excluding cement firms from the sample. This also holds when dropping all firms in sectors principally affected by excess capacity reductions under NAQAP.

Last, 2013 was only the starting year of NAQAP, which aimed to achieve results by 2017. Some of the most aggressive policies under NAQAP were only implemented in later years that are outside our sample period. This is true, for example, of the phase-out of small and polluting factories as well as for the tightening of emissions standards for industrial boilers.

5.2.4 Treatment heterogeneity and selection

The identification of the impact of the ETS could be affected by two additional aspects, namely (i) differences in policy design between Beijing and Hubei, and (ii) selection of large emitters into the policy. We discuss these in turn.

[21] We convert the 7 MW boiler capacity to 7,532 tce or 18,529 tCO_2 per annum (not accounting for downtime due to maintenance and other reasons). The Hubei participation threshold of 60,000 tce exceeds this by an order of magnitude. The Beijing threshold of 10,000 tCO_2 means that the small-boiler phase-out affected all untreated installations as well some treated installations with annual emissions between 10,000 and 18,529 tCO_2.

The pilot ETS in Beijing and Hubei were implemented independently and operated under different sets of rules concerning, for example, sector coverage, the cap on total allowances, and the thresholds for inclusion. Consequently, regulated firms in our sample exhibit stark differences across regions in terms of their energy use and fuel mix, both prior and after the introduction of the policy (cf. Table A.8). Heterogeneity in policy design is also reflected in the relevant survey responses which suggest a higher perceived stringency of the current and future ETS among Hubei firms (cf. Table A.5). To provide a sense of how the estimated treatment effects vary between the two ETS, Table B.5 reports the results of estimating equation (4) separately for the sub-samples of Beijing and Hubei firms. The impact of the ETS on coal use among well-managed firms is stronger in the former sub-sample whereas the coefficient for Hubei firms, while negative, is smaller and not significant. The same pattern is observed when the dependent variable is coal intensity. Hence the results in the full sample are likely driven by Beijing firms, which is not surprising given that they make up for 85% of the firms surveyed in our sample. Given this imbalance in the sample stratification, which is due to the much lower response rates in Hubei (4%) compared to Beijing (33%) (cf. Table A.2), it is not clear whether different point estimates for Hubei are due to differences in firm characteristics, heterogeneous ETS designs, or just an artifact of small-sample bias.

A key design feature concerns the definition of the cap on total allowances. As explained in Section 2.1, absolute emissions caps prevailed, but in selected sectors, total allowances were adjusted in relation to output. We gauge the impact of this feature on our results by estimating eq. (4) after excluding firms with intensity targets from the sample (firms in the power and heat sectors as well as cement firms in Hubei). The results reported in Table B.6 are very robust to this.

As mentioned in Section 3, energy usage and firm size differ significantly between ETS and non-ETS firms – not just across but also within regions. Bias could arise if unobserved determinants of the outcome variables were correlated with treatment. By virtue of using a DiD estimator, balance is not required to identify the average treatment effect of the ETS on the treated, as our econometric approach relies on the assumption that, if the policy had not been implemented, regulated firms would have continued to follow a similar trajectory as unregulated firms. While this "parallel-trends" assumption is not testable, we show in the next section that, in our energy consumption data, the hypothesis of parallel trends cannot be rejected for the pre-treatment period.

5.3 Panel-Data Regressions

The panel structure of the energy data allows us to check the robustness of the main results with respect to functional form assumptions, the treatment of unobserved heterogeneity, and the possible influence of pre-trends. Instead of averaging energy consumption values across years before and after the policy change, we now analyze year-to-year variation in energy use and check for trends in pre-treatment differences between treated and untreated firms. What is more, we use a fixed-effects approach instead of differencing, so as to control for unobserved heterogeneity at the firm level and for common shocks. To deal with zero values, and as an alternative to computing growth rates based on eq. (3), we estimate a Poisson model as in Silva & Tenreyro (2006),

$$e_{it} = \exp(\beta \mathbf{D_{it}} + \alpha_i + \alpha_t + \epsilon_{it}) \tag{6}$$

where e_{it} is the energy consumption of firm i in year t, and α_i, α_t are firm and year fixed effects, respectively.

Table 6 reports results for a specification where $\mathbf{D}_{it}$ contains $[ETSFirm_i \times Post2012_t$ and $ETSFirm_i \times AboveMedianCCM_i \times Post2012_t]$.[22] We find a strong negative effect of the pilot ETS on the consumption of coal for firms with above-median CCM values. The effect is of a similar order of magnitude as the results above and statistically significant at 1%. We find statistically insignificant negative effects on oil and electricity consumption.

We also estimate a version of eq. (6) in which $ETSFirm_i$ and $ETSFirm_i \times AboveMedianCCM_i$ are each interacted with a full set of year dummies. We plot the coefficient estimates from those interactions in Figure 2. The effect size is relative to the year 2010 which was the last year before plans for the ETS were announced by the Chinese government. We distinguish between a baseline period

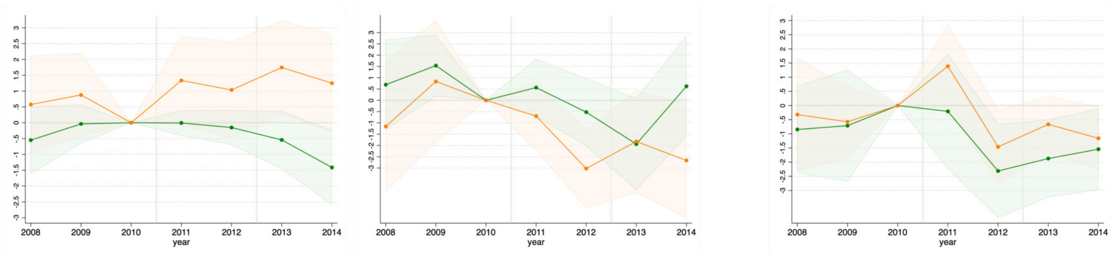
[22] Note that $ETSFirm_i$ and $AboveMedianCCM_i$ are absorbed by the firm fixed effect.

Table 6: ETS Impact - Poisson Specification (2008-2014)

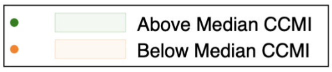
Dependent variables:	Coal (1)	Oil (2)	Electricity (3)
Variables			
ETS firm × Post 2012	0.559	-0.964	-0.257
	(0.365)	(1.147)	(0.488)
× Above-median CCMI	-1.297***	-0.855	-0.063
	(0.417)	(1.017)	(0.514)
Pseudo R^2	0.927	0.730	0.948
Number of observations	642	881	919
Number of firms	120	165	173

Notes: Poisson fixed-effect regressions. The dependent variables measure annual fuel consumption in tons of coal (column 1), tons of oil (column 2), electricity (in 10,000 Watts) (column 3), between 2008 and 2014. Above-median CCMI is a dummy indicating that an ETS firm is above the median of the CCM index. Further dummies indicate the regulatory status (ETS firm) and treatment period (Post 2012) of the ETS. Robust standard-errors (clustered at the firm level) in parentheses. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

Figure 2: Trends in Energy Consumption (2008-2014)



(a) Coal (b) Oil (c) Electricity



Notes. The figures plot year-specific treatment effects of the ETS on fuel consumption separately for firms with above-median CCM index (green) and the rest of the pack (red), relative to unregulated firms and against a 2010 baseline. The coefficient estimates are obtained from the interaction of the ETS regulation dummy, management tier, and year indicators in fixed-effect Poisson regressions where the dependent variable is coal use (panel a), oil use (panel b) and electricity use (panel c). Shaded areas represent 95% confidence intervals. Standard errors are clustered at the firm level.

(2008 to 2010), an announcement period (2011-2012), and the implementation period (2013-2014). In the baseline period, trends of coal consumption for non-ETS firms and ETS firms of any management type are closely aligned (this is shown more explicitly in Figure B.1 which does not distinguish by management quality). With the start of the announcement period, and especially during the implementation period, coal consumption declines at well-managed ETS firms relative to not well-managed ETS firms. For oil and electricity, usage trends of well-managed firms do not differ significantly from those of other firms. These results are robust to using a standard fixed-effect estimator, excluding observations with zero-coal consumption, and including year-by-region controls (see Figure B.2).

6 Implications for Policy

6.1 Exploring Mechanisms

Firms ranking higher on the CCM index respond to carbon pricing by reducing coal consumption and coal intensity relative to the rest of the pack. Does this mean that the former firms respond more rationally to the policy than the latter? Which aspects of climate-related management practices in particular are driving this response? The answers to these questions could inform the design of complementary policies aimed at enhancing the effectiveness of China's national ETS.

To break ground on this, we first explore which ones of ETS-related interview questions that do *not* enter the CCM index (described in Section 3.3) are good predictors of the CCM index after controlling for firm characteristics and interview noise. We implement this in the OLS regression equation

$$CCM_i = \alpha + \beta s_i + x_i'\gamma + z_i'\delta + u_i \quad (7)$$

where s_i is an ETS-related survey score, index or policy participation dummy not included in the CCM index. Table 7 reports the estimation results from four different regressions. The first column shows a positive and significant association between the CCM index and ETS participation, providing another sanity check for this index. Results in the next two columns use only variation *within* ETS firms,

Table 7: Climate Change Management and Trading Behavior

	Dependent variable: CCM index			
Explanatory variables:	ETS participation (1)	Rationality of current trading (2)	Stringency of current ETS (3)	Anticipated stringency of future ETS (4)
	0.355***	0.143*	0.182*	0.295***
	(0.097)	(0.074)	(0.093)	(0.054)
Number of firms	216	99	99	216
R^2	0.389	0.544	0.508	0.442
Adjusted R^2	0.194	0.123	0.055	0.264

Notes: OLS regressions of CCM index on four ETS trading-related behaviour. *ETS participation* is equal to one if the firm is part of the ETS, and zero otherwise. *Rationality*, *current stringency* and *anticipated stringency* are components of the CCMI and defined as the averages of the z-scores (see Appendix A.4 for the full list of questions). All regressions include *firm-level controls* and *interview 'noise' controls* as defined above. Robust standard errors in parenthesis are clustered at the firm level. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

which is relevant for explaining different treatment effects with respect to the CCM index. We find a positive correlation between the index and the rationality of the firm's trading behavior on the carbon market (column 2). Significant at 10%, this correlation is consistent with the notion that a manager who is capable of optimizing carbon trades is more prepared to measure and reduce the firm's energy consumption if this makes economic sense. Furthermore, the stringency of the ETS, either currently perceived by ETS firms (column 3) or as expected in a future national ETS by all firms (column 4), is a strong predictor of the CCM index. This provides suggestive evidence that in particular those managers who were more convinced that the nation-wide ETS would materialize were prepared to adopt climate friendly management practices. For the same reason, those managers might have been more pro-active about reducing consumption of high-carbon fuels like coal on site.

To investigate this further, we estimate our main specification (4) separately for each component of the CCM index. Histograms of those components, plotted in Figure A.2, reveal that climate change awareness, energy monitoring and energy targets are well stratified over the support, whereas there is relatively little variation in GHG monitoring, GHG targets, customer pressure, and, to a lesser extent, target enforcement. The results for growth in coal use, reported in Table 8, show only one statistically significant relationship: Firms with above-average energy monitoring responded to the ETS by strongly reducing coal use. Interest-

Table 8: ETS Impact on Growth of Coal Use by CCMI Components

	Dependent variable: ΔCoal						
Components:	Awareness	Energy use monitoring	Energy use target	GHG emissions monitoring	GHG emissions target	Target enforcement	Customer pressure
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ETS firm	-0.241	0.608	-0.233	-0.554	-0.007	-0.141	0.075
	(0.392)	(0.535)	(0.468)	(0.511)	(0.340)	(0.454)	(0.351)
Above-mean component	0.149	1.039**	-0.332	0.791	0.398	0.043	0.509
	(0.434)	(0.404)	(0.418)	(0.524)	(0.683)	(0.421)	(0.430)
× ETS firm	-0.161	-1.429**	0.046	-0.368	-0.879	-0.267	-0.901
	(0.571)	(0.626)	(0.593)	(0.722)	(0.772)	(0.576)	(0.566)
Number of firms	108	108	108	108	108	108	108
R^2	0.013	0.078	0.022	0.033	0.028	0.015	0.036
Adjusted R^2	-0.016	0.052	-0.007	0.005	0.000	-0.014	0.008

Notes: OLS regressions include a constant (not reported). The dependent variables are the midpoint growth rates, as defined in eq. (3), for tons of coal. The different components are described in Table A.4. All regressions include *firm-level controls* and *interview 'noise' controls* as defined above. Robust standard errors in parenthesis are clustered at the firm level. Robust standard errors in parentheses. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

ingly, no such relationship is found for monitoring GHG emissions or for setting targets for energy or emissions.[23]

Collectively, these results support the notion that more climate-friendly management practices, and in particular the detailed monitoring of energy consumption, led to stronger reductions of coal usage in response to carbon pricing. This is easily reconciled with the economics of market-based environmental regulation. Since coal is by far the most carbon-intensive fuel, the ETS imposes the strongest price increase on coal use. How elastically a firm responds to that price increase critically depends on how well it monitors its energy use. Only monitoring can reveal the potential for saving energy on site and provide the information on abatement costs and total compliance costs needed for rational responses to carbon pricing. In line with this, climate-friendly management practices overall are positively associated with a more broadly defined survey measure of rational behavior on the carbon market.

In view of these findings, we recommend giving firms access to energy monitoring technology as a straightforward policy to enhance the effectiveness and efficiency of China's nationwide carbon trading scheme as it is being rolled out across sectors.

[23]Table B.7 shows robustness of these results to using the 25th or 50th percentiles instead of the mean for defining good practices.

6.2 How Much Does Management Matter?

The statistical significance of the above findings does not automatically imply that they matter economically. To assess economic significance, we ask how much lower would coal consumption by ETS firms be if all of them had managers implementing only above-median climate change related management practices. We answer this by computing counterfactual growth rates of coal consumption as

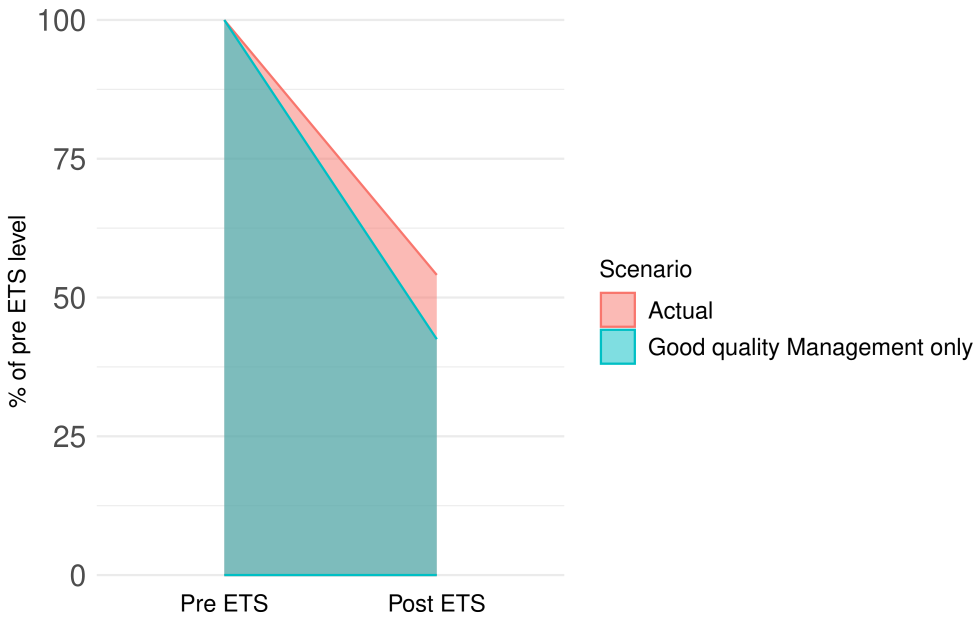
$$\gamma_i^{CF} = \gamma_i + (\beta_{CCM\times ETS} + \beta_{CCM}) \times ETSFirm_i \times BelowMedianCCM_i \qquad (8)$$

where we endow badly-managed ETS firms (i.e., those with a CCM index below the median) with the treatment effect estimated for well-managed ETS firms. To be conservative, we implement this using the estimates of $\beta_{CCM\times ETS}$ and β_{CCM} from column (2) of Table 4, which are smaller than their counterparts in Table 5. This adjusts growth in coal consumption at all badly-managed ETS firms by the average difference to well-managed ETS firms, leaving growth rates at all other firms unaffected. Using eq. (3), we then back out the counterfactual level of consumption for firm i as

$$e_i^{post,CF} = e_i^{pre} \times \frac{1 + 0.5\gamma_i^{CF}}{1 - 0.5\gamma_i^{CF}}. \qquad (9)$$

Figure 3 shows that aggregate coal consumption by ETS firms in our sample decreased by around 46% when comparing the periods before and after 2013. Under the counterfactual assumption that all ETS firms had above-median management quality, their coal consumption would have decreased instead by about 57% from pre-ETS levels. Put differently, the treatment effect could have been 25% greater if badly managed firms had been well managed. Energy monitoring alone accounts for half of this improvement; if all firms had above-average energy monitoring the treatment effect of the ETS would have been 13% greater. From this we conclude that management quality has an economically significant impact on the extent to which energy-intensive businesses in China respond to carbon pricing.

Figure 3: Counterfactual Reduction in Coal Consumption



Notes. The graph shows the reduction in coal consumption by ETS firms following the introduction of the ETS, as a percentage of pre-ETS levels. Pink refers to the observed, green to a counterfactual scenario where all ETS firms are well managed with respect to climate change related management practices. The counterfactual is obtained by adjusting the observed growth in coal consumption for the estimated treatment effect on well-managed firms. See the text for full details.

7 Conclusions

China – the world's largest emitter of greenhouse gases – has pledged to become carbon neutral by 2060 and has been embracing market-based approaches for achieving this goal. In this study, we have analyzed how management quality moderates the effectiveness of such a policy in the context of pilot carbon trading schemes in two regions. A key ingredient of our study is a new index of management practices related to climate change which we constructed based on interviews with Chinese managers. Our study breaks new ground by combining this kind of information with a quasi-experimental evaluation of a cap-and-trade program.

Our main finding is that firms regulated under the ETS reduced their consumption of high-carbon fuels more strongly than unregulated firms, and that this is statistically significant only for firms that ranked above the median value of our index, i.e. those that are well-managed w.r.t. climate change. Our econometric estimates imply that, in a counterfactual experiment where good management practices are substituted for bad ones, the reduction in coal consumption would have been 25% larger. We attribute this result to the fact that understanding the trade-off between using, selling or banking a pollution permit is more demanding than simply complying with a quota or standard. Based on our result we conclude that complementary policies, such as giving firms access to energy monitoring technology, are needed to enhance the effectiveness of the nation-wide ETS that currently covers power and heat installations and will soon be extended to other heavy polluting industries.

Caveats arise mainly from data limitations. We found hesitation to participate in an interview to be more wide-spread among Chinese managers than in other countries. This is reflected in lower-than-usual response rates. Further limitations concern the energy data, which is not available for 2015 or later years. Finally, we did not have access to data on permit holdings and trading behavior, which would be required to study compliance strategies other than onsite CO_2 abatement. These imperfections have prevented us from employing some of the more sophisticated techniques from the toolbox of program evaluation, but the novelty of the data allows us to make valuable recommendations for the development of carbon markets.

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Appendices

A Data

A.1 Interview data

This appendix provides more details on the data collection made through the survey. From the summer of 2016 to the end of 2017, a team of 22 post-graduate students at ShanghaiTech University conducted the survey through telephone interviews with industrial firms located in Beijing and Hubei.[24] Firms were randomly selected from the ORBIS database that also contains contact details. When contacting firms, interviewers requested to speak to the managers or engineers in charge of environmental issues at the operation facilities. Following the BVR methodology, the interviewers asked open-ended questions starting with those that are more general and broad (e.g., How is pollution discussed within your business?) followed by more specific queries (e.g., Did you commission reports or studies on how pollution/climate change will affect your business?). Interviewers will ask for examples so that they can form a reasonable assessment of the interviewee's responses. Based on a response assessment grid described relative to the questionnaire, the interviewers will provide a score between 1 and 5 with a higher score representing better performance.

Response rates The sampling frame starts with the set of firms in the ORBIS dataset located in Hubei and Beijing in all sectors that include firms regulated by the pilot ETS. This corresponds to 5,707 firms with reported turnover. Drawing at random, firms were contacted until an interview was agreed to or refused. ETS firms were oversampled so that between 40 and 60 percent of managers interviewed in each region worked at an ETS firm. Non-ETS firms were contacted at random. Sample selection bias could occur if the characteristics of firms that were contacted, or agreed to be interviewed, differed in systematic ways. Out of 1,644 contacted firms, 1,360 firms refused to participate or ceased operation or declined our requests

[24] Some of the interviews were conducted by Chinese graduate students at Imperial College Business School and the London School of Economics.

Table A.1: Sample Selection

Dependent variables:	Turnover (1)	Capital (2)	Employment (3)
A. All firms:			
Firm contacted	-30.646	-4.631	4.059
	(32.171)	(5.915)	(17.872)
ETS firm	521.190***	78.782*	129.512
	(128.019)	(43.432)	(160.411)
Number of observations	32,026	32,090	18,393
Number of firms	5,707	5,681	5,472
R^2	0.341	0.427	0.448
B. Contacted firms:			
Firm granted interview	-32.628	7.508	15.662
	(44.386)	(15.041)	(55.851)
ETS firm	379.281**	24.583	-7.263
	(171.506)	(72.267)	(293.557)
Number of observations	10,382	10,327	5,617
Number of firms	1,514	1,513	1,499
R^2	0.421	0.463	0.387

Notes: Regressions in panel A are based on the set of firms in ORBIS for Hubei and Beijing in sectors similar to firms regulated in the ETS and include an indicator of whether the firm was contacted. Panel B reports analogous regressions for the set of contacted companies and with an indicator for whether the interview was granted. Turnover and capital are measured in millions of USD, while employment is in tens of employees. All regressions include a constant (not reported) and 3-digit NACE sector dummies and year dummies. Standard-errors in parentheses are clustered at the firm level and are robust. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

to talk to their managers. In Table A.1, we conduct a comparison of key firm characteristics - turnover, capital and employment - between the firms that were contacted or not (Panel A), and between those that were interviewed and those that were not (Panel B), controlling for the firms' participation in the ETS. We find no statistically significant evidence of a sample selection bias on observable characteristics. In total, we interviewed managers from 216 firms successfully. Among these firms, 183 out of the 216 firms were located in Beijing city, and 33 firms were located in Hubei province. Compared to Beijing, firms in Hubei province appear more averse to accepting interviews which could be due to the culture, business sentiment, and the lack of exposure to survey interview experience. Hence, it was particularly challenging to obtain interviews with firms in Hubei especially after the province was affected by a major flood in 2017. On average, an interview lasted 35 minutes.

Table A.2: Survey Response Rates by ETS Location

	Total firms contacted	No. of ETS firms successfully interviewed	No. of non-ETS firms successfully interviewed	Refused/non-contactable	No. of firms successfully interviewed	Response rate
Beijing	750	80	103	502	183	33.07%
Hubei	894	19	14	858	33	4.03%
Total	1,644	99	117	1,360	216	17.27%

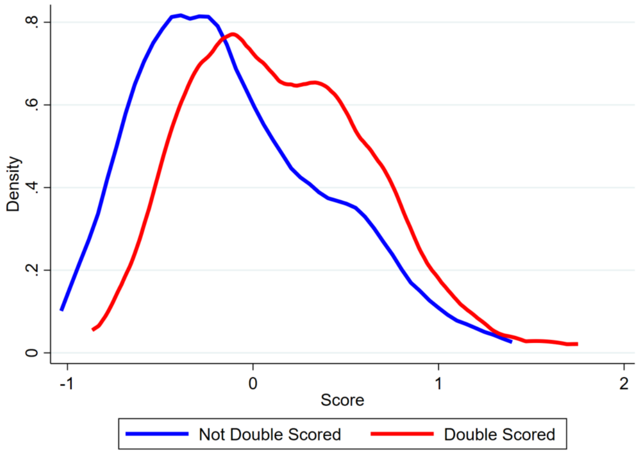
Notes: The non-contactable firms include those firms which ceased operation and failed attempts to engage contact despite multiple call-backs. It also includes those firms that refused to allow contact with their staff if interviewers could not provide the exact name and title of the person they wished to speak to.

Double scoring In 90 of the 216 firm interviews, a second interviewer listened to the interview silently and scored the responses simultaneously and independently. This 'double scoring' provided a consistency check of the scores. Figure A.1 plots the distributions of the climate change management index for firms with and without double-scoring. It can be seen that the mean value of the environmental management index for firms that had been double-scored is higher than firms that had not been double-scored. This could reflect that interviewers are indeed subjective in their assessment of each question despite the provision of benchmark examples. However, when the CCM index is regressed on the double-score assignment while controlling for the interviewer fixed effect, the effect of double-score is not statistically significant. This suggests that the interviewer bias can be controlled by using the interviewer fixed effect in regression estimates.

Constructing the CCM Index and Sub-Indices Table A.4 lists descriptive statistics of the 21 components that are averaged to generate the CCM index.

Summary Statistics by region and ETS status Table A.5 presents descriptive statistics of the resulting sample by region and ETS status, i.e. whether the firm is regulated in the pilot ETS.

Figure A.1: Double Scoring



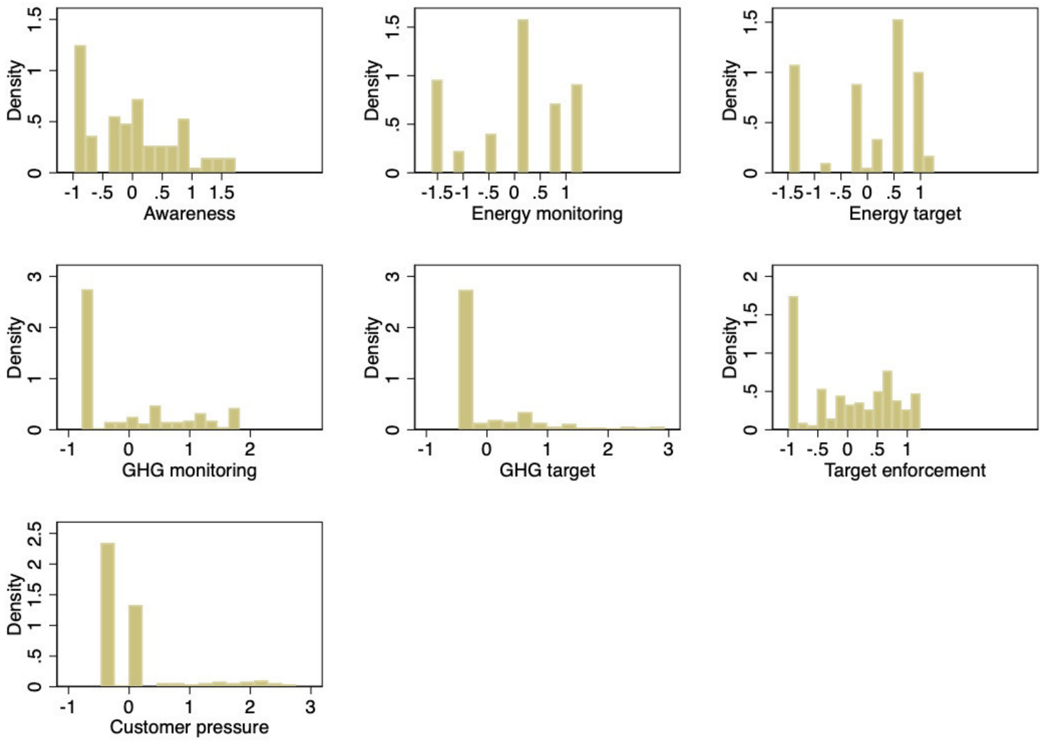
Notes: This figure compares the Kernel density distributions of the CCM index of firms that were double scored and were not double scored.

Table A.3: Raw correlations of Climate Change Management Index with firm characteristics

	Correlation	*p*-values
Employment	0.168**	0.016
Labor intensity	-0.053	0.435
Capital	0.219***	0.001
Turnover	0.148**	0.030
Coal use	0.171**	0.022
Oil use	0.063	0.063
Electricity use	0.211***	0.004
Firm Age	0.046	0.498
Manager Tenure	0.098	0.160
State-Owned Enterprise [dummy]	0.132*	0.053
ETS Firm [dummy]	0.451***	0.000
Beijing [dummy]	-0.170**	0.012

Notes: The table reports bivariate correlation coefficients between the Climate Change Management (CCM) index and various firm characteristics. Labor intensity is defined as employment divided by turnover. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

Figure A.2: Distribution of Climate Change Management Index: Components



Notes: The figure shows histograms of the distribution of climate-centric management practices separately for each component, which are the basis of the Climate Change Management Index, as described in Table A.4.

Table A.4: Climate Change Management Index Components

			Mean	S.D.
Awareness	How is pollution discussed within your business? Can you give examples?	5-points scale	3.13	1.29
	Can you give examples of occurrences where pollution is formally discussed in management meetings?	5-points scale	3.10	1.38
	Can you tell me how different the discussions or management and strategic decisions around climate change are different to those on pollution? Can you give some examples?	0-1 dummy	0.15	0.36
Energy monitoring	How detailed is your monitoring of energy usage?	5-points scale	2.75	1.71
Energy consumption targets	Do you have any targets on energy consumption which management has to observe? (e.g. kWh of electricity)	0-1 dummy	0.76	0.43
	Can you describe some of the challenges you face in meeting these targets?How often do you meet these targets? Do you think they are tough?	5-points scale	2.46	1.29
GHG emissions monitoring	Do you explicitly monitor your carbon emissions? Since when?	5-points scale	1.97	1.38
	How do you estimate your carbon emissions?	5-points scale	2.17	1.48
	Are your carbon estimates externally validated?	5-points scale	2.43	1.76
GHG emissions targets	Do you have any absolute targets on carbon emissions which management has to observe?	0-1 dummy	0.22	0.42
	How about any carbon emissions targets relative to your company production of output?	5-points scale	1.61	1.03
	Can you describe some of the challenges you face in meeting the targets?	5-points scale	1.27	0.75
	How often do you meet these targets? Do you think they are tough? Note: If the manager replies they have CCETS targets, ask: Have these been translated into internal targets for management? Recode this as evidence for degree of difficulty in meeting targets.	5-points scale	1.32	0.89
Target enforcement	What happens if energy consumption or GHG emission targets are not met?	5-points scale	2.46	1.49
	Do you publicize targets and target achievement within the firm or to the public? Can you give examples? Are there financial consequences in case of non-achievement?	0-1 dummy	0.62	0.49
	Are there non-financial consequences in case of non-achievement?	0-1 dummy	0.45	0.50
	Is there a bonus for target achievement?	0-1 dummy	0.39	0.49
Customer pressure	Are your customers concerned about your GHG emissions?	5-points scale	1.30	0.80
	How do they voice this concern?	5-points scale	1.31	0.84
	Do your customers require hard data on your carbon emissions?	0-1 dummy	0.09	0.29
	Are your customers concerned about the standard of 'green' management or production of your company? If so, to what extent?	0-1 dummy	0.41	0.49

Table A.5: Summary Statistics and Sample Characteristics by ETS status

	ETS	non-ETS		Beijing ETS	Beijing non-ETS		Hubei ETS	Hubei non-ETS	
	Mean	Mean	p-value	Mean	Mean	p-value	Mean	Mean	p-value
Interview characteristics data									
Manager's tenure in company in years	11.24	8.76	0.01	11.12	9.06	0.05	11.72	6.61	0.10
Manager's tenure in position in years	5.27	6.67	0.05	5.32	6.83	0.05	5.07	5.5	0.82
Manager's education in business management	0.47	0.55	0.29	0.49	0.59	0.18	0.39	0.21	0.31
Manager is female	0.18	0.19	0.91	0.2	0.17	0.67	0.11	0.29	0.20
Manager's age in years	38.82	39.33	0.67	38.08	39.23	0.36	41.58	40.07	0.67
Firm's age in years	20.77	19.23	0.15	22.16	19.84	0.04	14.89	14.71	0.93
Firm is state-owned	0.57	0.26	0.00	0.59	0.28	0.00	0.47	0.07	0.01
Firm engages in export	0.46	0.48	0.79	0.5	0.49	0.89	0.22	0.42	0.37
Management index									
CCM index	0.24	-0.21	0.00	0.24	-0.26	0.00	0.26	0.12	0.48
Carbon market indices									
Participant in pilot ETS market	1	0		1	0		1	0	
Rationality of current trading score	1.77			1.79			1.64		
Stringency of current pilot ETS index	0.07	-0.74	0.00	0.02	-0.77	0.00	0.28	-0.08	
Anticipated stringency of future ETS index	0.18	-0.38	0.00	0.11	-0.4	0.00	0.48	-0.27	0.01
Green Innovation									
Process innovation score	1.96	1.48	0.00	2	1.43	0.00	1.81	1.81	0.99
Product innovation score	2	1.91	0.55	1.98	1.87	0.56	2.11	2.14	0.93
Innovation index	1.98	1.69	0.02	1.99	1.65	0.01	1.96	1.98	0.95
Firm has green patent	0.58	0.37	0.10	0.62	0.36	0.07	0.40	0.4	1.00
Share of green patents	0.12	0.09	0.54	0.14	0.1	0.47	0.03	0.03	1.00
ORBIS data									
Turnover in 000's USDs	313,317	26,156	0.00	340,238	27,457	0.00	139,924	14,881	0.00
Employment	2,402	295	0.00	2,613	301	0.00	1,152	253	0.00
Capital in 000's USDs	235,923	12,738	0.00	256,265	11,018	0.00	102,250	27,579	0.00
Cost of goods sold in 000's USDs	244,312	19,702	0.00	262,453	20,523	0.00	127,030	12,540	0.00
Firm energy usage									
Oil usage in 000's tons	2,327	281	0.01	2,342	203	0.01	2,244	1,106	0.56
Coal usage in 000's tons of oil equivalent	72,300	312	0.00	37,997	246	0.00	272,309	1,016	0.00
Electricity usage in megawatts	6,248	253	0.00	4,834	162	0.01	14,489	1,220	0.00
Oil intensity in tons of oil per million USD	90	28	0.09	98	14	0.03	44	181	0.17
Coal intensity in tons of coal per million USD	822	31	0.00	662	23	0.00	1,757	114	0.00
Electricity intensity in megawatts per million USD	171	25	0.22	180	22	0.24	123	60	0.14

A.2 Energy Data

Table A.6: Non-Zero Observations by Year

Year	Coal	Oil	Electricity
2008	57	106	131
2009	54	110	133
2010	45	88	38
2011	70	117	38
2012	64	106	136
2013	89	119	119
2014	26	62	72

Notes: Number of firms consuming a positive amount of energy by type in the panel dataset used for the analysis in Section 5.3.

Table A.7: Energy Data Availability

	Numbers of non-missing years			Numbers of non-zero years			Included in CSAT		
Dependent variables:	Coal (1)	Oil (2)	Elec (3)	Coal (4)	Oil (5)	Elec (6)	Coal (7)	Oil (8)	Elec (9)
ETS firm	0.558	0.551	0.558	0.547	0.247	0.583	0.129	0.065	0.067
	(0.622)	(0.620)	(0.622)	(0.479)	(0.553)	(0.468)	(0.096)	(0.088)	(0.085)
Hubei firm	-1.881**	-1.860**	-1.881**	-0.455	-1.449*	-0.358	0.002	-0.155	-0.083
	(0.826)	(0.826)	(0.826)	(0.665)	(0.748)	(0.703)	(0.129)	(0.136)	(0.134)
Above-median employment	0.298	0.295	0.298	0.204	0.005	0.151	0.019	0.041	0.111
	(0.597)	(0.597)	(0.597)	(0.494)	(0.558)	(0.445)	(0.103)	(0.091)	(0.089)
Above-median capital	0.818	0.812	0.818	-0.480	-0.207	0.543	0.017	0.084	0.121
	(0.592)	(0.592)	(0.592)	(0.462)	(0.524)	(0.423)	(0.104)	(0.093)	(0.092)
Above-median turnover	0.010	0.005	0.010	0.502	0.183	-0.230	0.127	-0.024	-0.046
	(0.599)	(0.599)	(0.599)	(0.499)	(0.563)	(0.445)	(0.116)	(0.098)	(0.096)
State-owned	-0.654	-0.664	-0.654	-0.060	-0.470	-0.706*	-0.080	-0.088	-0.098
	(0.502)	(0.501)	(0.502)	(0.389)	(0.485)	(0.382)	(0.081)	(0.079)	(0.078)
Above median firm age	-0.101	-0.084	-0.101	-0.080	0.031	-0.043	0.059	-0.005	-0.026
	(0.469)	(0.467)	(0.469)	(0.370)	(0.453)	(0.365)	(0.079)	(0.075)	(0.073)
Above-median CCM index	-0.272	-0.270	-0.272	0.483	0.016	-0.222	0.044	0.040	0.019
	(0.532)	(0.531)	(0.532)	(0.408)	(0.487)	(0.420)	(0.085)	(0.081)	(0.079)
Number of firms	216	216	216	216	216	216	216	216	216
Adjusted R^2	0.034	0.035	0.034	0.101	0.027	0.016	0.012	0.017	0.023

Notes: OLS regressions include a constant (not reported). The dependent variables are the number of years, out of the nine years of the data, without missing energy data for each of the respecting fuels in the first three columns (coal, oil and electricity). The dependent variables in columns 4-6 are the number of years without zeros, excluding the missing observations. Columns 7-9 are indicators of whether the firm was in the CSAT dataset. Regressions include sector dummies and *interview 'noise' controls* defined in the main paper. Robust standard-errors are in parentheses. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

Table A.8: Firm energy usage by ETS status

	All firms		ETS firms		non-ETS firms	
	pre-ETS	post-ETS	pre-ETS	post-ETS	pre-ETS	post-ETS
	Mean	Mean	Mean	Mean	Mean	Mean
Beijing Firms						
Oil usage in 000's tons	1489.12	161.46	3086.64	213.55	229.11	110.92
Coal usage in 000's tons of oil equivalent	21116.88	5440.82	47497.48	10757.72	235.34	281.84
Electricity usage in megawatts	2833.49	521.73	6189.06	950.43	177.39	105.77
Oil intensity in tons of oil per million USD	66.19	5.56	130.76	2.34	15.07	8.69
Coal intensity in tons of Coal per million USD	385.8	81.53	847.2	131.02	20.57	33.52
Electricity intensity in megawatts per million USD	120.83	7.22	239.69	7.92	26.75	6.54
Hubei Firms						
Oil usage in 000's tons	700.64	4625.63	657.02	6086.53	763.34	2102.27
Coal usage in 000's tons of oil equivalent	155908.9	186096.5	263683.1	293193	983.44	1111.73
Electricity usage in megawatts	7663.92	13215.67	12565.8	19145.68	617.47	2972.91
Oil intensity in tons of oil per million USD	62.54	192.86	11.03	124.67	136.59	310.64
Coal intensity in tons of COAL per million USD	1124.09	1048.32	1808.49	1632.62	140.26	39.09
Electricity intensity in megawatts per million USD	99.75	92.55	138.74	85.03	43.7	105.53

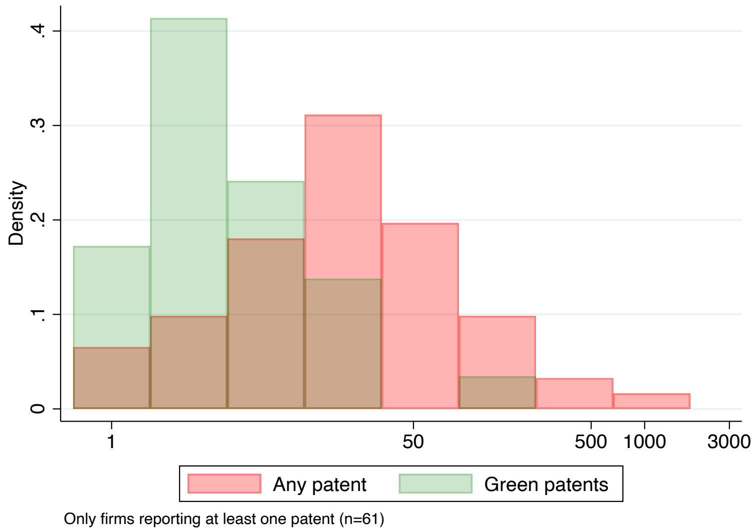
Table A.9: Energy consumption by management quality and ETS

			Coal		Oil		Electricity	
ETS firm	CCMI	N	mean	sd	mean	sd	mean	sd
Non-ETS	below-median	59	222	669	125	473	277	874
	above-median	21	532	1151	801	2297	184	390
ETS	below-median	16	13719	41612	6029	16072	2138	3529
	above-median	56	123447	424952	1818	8310	6378	15782
	All	152	47084	263416	1464	7390	2708	10025

Notes: Descriptive statistics for the energy consumption variables before the introduction of the ETS in 2013. We report separate figures for well managed (above-median) and not so well managed (below-median), as well as ETS and non ETS regulated firms.

A.3 Patent Data

Figure A.3: Patent Holdings Across Firms



B Additional Results

B.1 Climate-Friendly Management and Energy Intensity

Table B.1: Climate Change Management Index and Energy Intensity

	Coal Intensity (1)	Oil Intensity (2)	Electricity Intensity (3)	Log Turnover (4)	Log Turnover (5)
CCM index	0.399	0.187	0.213	0.150**	0.164**
	(0.637)	(0.235)	(0.183)	(0.063)	(0.063)
Hubei firm	2.674***	0.132	3.130***	-0.009	-0.017
	(0.835)	(0.379)	(0.357)	(0.081)	(0.072)
State-owned	0.575	0.951****	0.360*	0.069	0.047
	(0.516)	(0.246)	(0.209)	(0.061)	(0.057)
Log(Capital)	0.002	-0.072	0.088	0.153***	0.119***
	(0.127)	(0.062)	(0.067)	(0.038)	(0.037)
Log(Employment)	0.049	0.005	0.185	0.064	0.037
	(0.157)	(0.090)	(0.164)	(0.050)	(0.044)
Log(Cost of Goods Sold)	-0.371**	-0.482***	-0.465***	0.729***	0.802***
	(0.183)	(0.091)	(0.153)	(0.072)	(0.052)
Number of observations	405	709	667	1572	1286
Number of firms	121	166	174	216	215
R^2	0.596	0.456	0.509	0.896	0.912
Adjusted R^2	0.530	0.407	0.461	0.891	0.908

Notes: OLS regressions, constant not reported. The dependent variables are the logarithms of tons of coal per million turnover in USD (column (1)), tons of oil per million USD of turnover (column (2)), MegaWatts electricity per million turnover in USD (column (3)); and log of turnover (column (4)). All columns include *firm-level controls* and *interview 'noise' controls* as defined in the paper. Robust standard errors given in parenthesis are clustered at the firm level. Significance levels are indicated as * 0.10, **0.05, *** 0.01.

B.2 Individual Management Practices, Productivity, and Energy Intensity

To shed light on which particular management practices might be driving the results on the CCM index, we decompose the index into scores and sub-indices, also computed using the z-scores of raw scores. The CCM index is decomposed into seven components as described in Table A.4 and Figure A.2: awareness, energy and GHG emissions monitoring and targeting, target enforcement and customer pressure. For instance, the climate change awareness index includes awareness scores that indicate how thoroughly climate change and pollution is being discussed among employees of the firm and to what extent this discussion takes place at the management level. The monitoring scores reflect how detailed the monitoring of energy consumption, or GHG emissions is within the firm. The energy consumption and GHG emissions targets measure whether the firm has targets that management has to observe and how challenging it is to meet these targets. The target enforcement index seeks to indicate how consequential it is to meet or not the target. Finally, the customer pressure index combines information about how demanding customers are about GHG emissions and the standards of green management.

On the basis of these components, we estimate eq. (1) using only particular management practices instead of the overall CCM index. The results are presented in Table B.2, where each cell corresponds to one regression. The dependent variable in columns (1) and (2)is the logarithm of turnover but since we also control for employment (column 1) and, additionally, for capital and materials (column 2), the coefficients can be interpreted as a correlation between the management measure and labor productivity or total factor productivity, respectively. We find that the positive association of the CCM index with these productivity measures is mainly driven by energy and GHG monitoring as well as the target enforcement score, which measures the stringency of the enforcement of targets on energy consumption and emissions targets.

Table B.2 also examines how specific management practices correlate with physical measures of the energy intensity of production also used in Table B.1. Column (3) shows that all management practices are negatively associated with oil

Table B.2: Management Score Components

	Turnover (Lab. prod.) (1)	Turnover (TFP) (2)	Oil Intensity (3)	Coal Intensity (4)	Electricity Intensity (5)
Awareness	0.319**	0.069	-11.567	-91.919	49.858
	(0.134)	(0.050)	(21.883)	(106.350)	(63.207)
Energy monitoring	0.353***	0.070*	-53.948***	62.606	-3.266
	(0.093)	(0.039)	(19.122)	(51.180)	(36.314)
Energy target	0.188*	0.023	-13.773	83.790	37.949
	(0.101)	(0.029)	(13.727)	(75.563)	(38.241)
GHG monitoring	0.521***	0.087**	-1.370	83.951	127.672
	(0.109)	(0.043)	(20.608)	(123.432)	(110.140)
GHG targets	0.212**	0.032	-49.730**	-92.622	81.396
	(0.097)	(0.029)	(24.144)	(134.329)	(72.206)
Target enforcement	0.212**	0.063*	-31.641	267.442**	38.677
	(0.104)	(0.037)	(20.412)	(114.997)	(49.452)
Customer pressure	0.180*	0.041	-28.627	-29.037	-83.768
	(0.107)	(0.028)	(21.699)	(61.118)	(96.867)
Number of observations	1,572	1,572	1,103	1,103	1,103
Number of firms	216	216	182	182	182

Notes: Each cell represents the result of a separate OLS regression using different indices as dependent variables. The dependent variable is defined as logarithm of turnover in columns (1) and (2), oil intensity in column (3) [tons of oil per million USD], coal intensity in column (4) [tons of coal per million USD], and electricity intensity in column (5) [MegaWatts per million USD]. All regressions include *firm-level controls* and *interview 'noise' controls* defined in the main paper. In column (2), logarithm of cost of goods sold and logarithm of fixed assets obtained from the ORBIS database are included. Lab.prod. stands for labor productivity and TFP for total factor productivity. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

intensity, and statistically significantly so for energy monitoring and GHG target setting. This result is consistent with a causality running from better conservation efforts by management to reduced fuel use. However, our estimates could also be driven by selection if more energy intensive firms deliberately adopt targets on energy use or emissions, and put more effort into enforcing them. This is illustrated by the positive correlation between target enforcement and coal intensity (in column 4). The opposing direction of causal and selection effects could explain why many most estimates are not significantly different from zero at conventional levels.

B.3 Manager Tenure and ETS

Table B.3: New management and ETS participation

Dependent variable:	New Manager since the start of ETS			
	(1)	(2)	(3)	(4)
ETS firm	0.020	0.088	0.100	0.064
	(0.087)	(0.123)	(0.141)	(0.212)
Above-median CCM index		0.027	0.042	0.146
		(0.114)	(0.119)	(0.186)
× ETS firm		-0.108	-0.122	-0.099
		(0.167)	(0.172)	(0.232)
SOE			-0.019	-0.022
			(0.089)	(0.141)
Above-median dummies:				
employment			0.019	0.166
			(0.101)	(0.152)
capital			-0.134	0.090
			(0.095)	(0.181)
turnover			0.086	-0.266
			(0.107)	(0.168)
age			0.056	-0.048
			(0.078)	(0.117)
coal use				0.097
				(0.152)
Number of firms	216	216	216	108
Adjusted R^2	0.015	0.007	-0.008	0.025

Notes: OLS regressions include a constant (not reported). The dependent variable is a dummy equal to one if the interviewed manager's tenure in the current post has been less than five years, i.e. since the start of the ETS at the time of interview. All regressions include *firm-level controls* and *interview 'noise' controls* as in the main paper. Robust standard-errors in parentheses. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

B.4 Results by Sub-Samples

Table B.4: ETS Impact on Coal Use: Robustness in Subsamples

	Full	w/o Power	w/o Power & Cement	w/o Power, Cement, Iron & Steel, Flat Glass
	(1)	(2)	(3)	(4)
A. Growth of energy use				
ETS firm	0.724	0.724	0.803	0.789
	(0.460)	(0.461)	(0.546)	(0.549)
Above-median CCM index	0.375	0.375	0.535	0.522
	(0.470)	(0.471)	(0.488)	(0.491)
× ETS firm	-1.499**	-1.383**	-1.657**	-1.643**
	(0.640)	(0.646)	(0.725)	(0.727)
Number of firms	108	102	92	91
R^2	0.065	0.051	0.064	0.064
Adjusted R^2	0.038	0.022	0.032	0.032
B. Growth of energy intensity				
ETS firm	0.556	0.556	0.650	0.628
	(0.476)	(0.476)	(0.562)	(0.565)
Above-median CCM index	0.221	0.221	0.350	0.328
	(0.501)	(0.502)	(0.529)	(0.532)
×ETS firm	-1.261*	-1.142*	-1.379*	-1.357*
	(0.669)	(0.675)	(0.761)	(0.764)
Number of firms	108	102	92	91
R^2	0.057	0.041	0.049	0.049
Adjusted R^2	0.029	0.011	0.016	0.017

Notes: OLS regressions include a constant (not reported). The dependent variable is the midpoint growth rate of coal usage (Panel A) and coal intensity (Panel B). Compared to column 1, which is based on the full sample, column 2 excludes the power sector, column 3 excludes both the power and cement sectors, and column 4 excludes power as well as all sectors principally affected by capacity reductions (i.e., cement, iron and steel, and flat glass). Robust standard-errors in parentheses. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

Table B.5: ETS Impact on Growth of Energy Use and Energy Intensity by Region

Dependent variables:	ΔFuel			ΔFuel Intensity		
Samples:	Full Sample	Beijing	Hubei	Full Sample	Beijing	Hubei
	(1)	(2)	(3)	(4)	(5)	(6)
A. Coal						
ETS firm	0.724	0.701	1.449	0.556	0.562	0.957
	(0.460)	(0.549)	(0.988)	(0.476)	(0.565)	(1.186)
Above-median CCM index	0.375	0.601	0.286	0.221	0.542	-0.402
	(0.470)	(0.531)	(1.134)	(0.501)	(0.559)	(1.264)
× ETS firm	-1.499**	-1.847**	-0.829	-1.261*	-1.706**	-0.053
	(0.640)	(0.751)	(1.226)	(0.669)	(0.778)	(1.373)
Number of firms	108	93	15	108	93	15
R^2	0.065	0.091	0.165	0.057	0.085	0.143
Adjusted R^2	0.038	0.060	-0.062	0.029	0.054	-0.091
B. Oil						
ETS firm	-0.354	-0.288	-1.517	-0.268	-0.214	-1.439
	(0.369)	(0.372)	(1.286)	(0.370)	(0.367)	(1.326)
Above-median CCM index	-0.120	0.154	-2.534***	-0.069	0.215	-2.593***
	(0.293)	(0.295)	(0.770)	(0.296)	(0.302)	(0.694)
×ETS firm	0.146	-0.176	2.827*	0.101	-0.246	2.994*
	(0.482)	(0.487)	(1.510)	(0.484)	(0.487)	(1.502)
Number of firms	145	128	17	145	128	17
R^2	0.016	0.023	0.224	0.008	0.019	0.235
Adjusted R^2	-0.005	-0.001	0.045	-0.013	-0.005	0.058
C. Electricity						
ETS firm	0.249	0.218	-0.308	0.277	0.283	-0.320
	(0.383)	(0.450)	(0.733)	(0.382)	(0.453)	(0.792)
Above-median CCM index	0.334	0.140	1.099	0.151	-0.037	0.928
	(0.331)	(0.323)	(0.697)	(0.321)	(0.302)	(0.928)
×ETS firm	-0.848	-0.825	-0.464	-0.720	-0.704	-0.446
	(0.514)	(0.558)	(1.003)	(0.503)	(0.546)	(1.192)
Number of firms	152	131	21	152	131	21
R^2	0.030	0.048	0.187	0.026	0.046	0.106
Adjusted R^2	0.010	0.026	0.043	0.006	0.023	-0.052

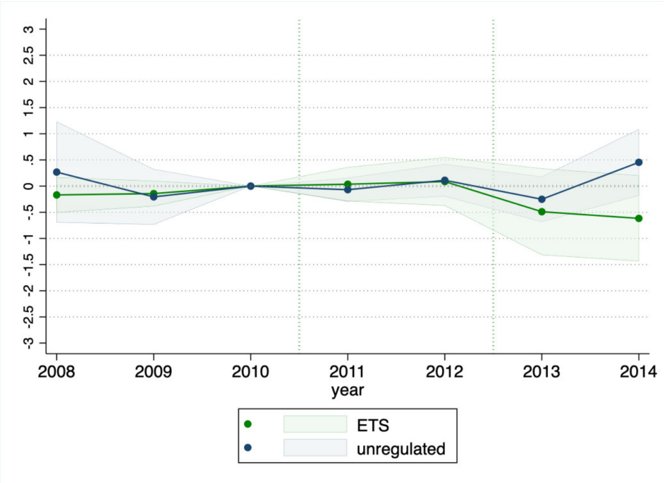
Notes: OLS regressions include a constant (not reported). The dependent variable is the midpoint growth rate of fuel usage (columns (1)-(3)) and fuel intensity defined as fuel usage over turnover (columns 4-6). Columns (1) and (4) are for the full sample, columns (2) and (5) are restricted to Beijing firms, and columns (3) and (6) are restricted to Hubei firms. Panel A (B) focuses on the growth rate of coal (oil) in tons, or the growth rate of coal (oil) intensity defined as coal usage in tons over turnover. Panel C focuses on the growth rate of electricity in 10,000 watts or the growth rate of electricity intensity defined as electricity usage in 10,000 watts over turnover. Robust standard-errors in parentheses. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

Table B.6: ETS Impact on Energy Use in Sectors with an Absolute Cap

	Growth				Intensity growth			
Dependent variables:	ΔCoal	ΔCoal	ΔOil	ΔElec	ΔCoal	ΔCoal	ΔOil	ΔElec
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ETS firm	-0.283	0.748	-0.427	0.039	-0.325	0.593	-0.364	0.085
	(0.293)	(0.545)	(0.356)	(0.399)	(0.299)	(0.561)	(0.353)	(0.403)
Above-median CCM index		0.375	-0.120	0.334		0.221	-0.069	0.151
		(0.471)	(0.294)	(0.332)		(0.502)	(0.297)	(0.321)
× ETS firm		-1.500**	0.259	-0.686		-1.259*	0.232	-0.569
		(0.710)	(0.480)	(0.533)		(0.739)	(0.480)	(0.525)
Number of firms	97	97	134	139	97	97	134	139
R^2	0.01	0.058	0.016	0.030	0.012	0.048	0.010	0.023
Adjusted R^2	0.001	0.028	-0.007	0.008	0.002	0.018	-0.013	0.001

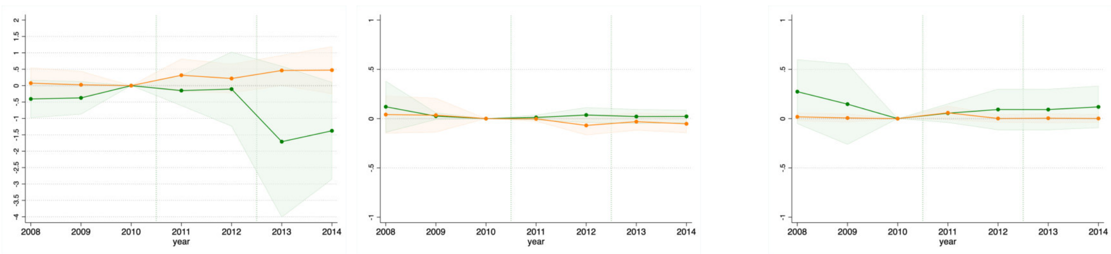
Notes: OLS regressions include a constant (not reported). The dependent variables are the midpoint growth rates, as defined in eq. (3), for tons of coal (columns (1) and (2)), tons of oil (column (3)) and electricity (in 10,000 Watts) (column (4)). The same outcome variables are reported in columns (5)-(8) but measured as intensity growth (growth of fuel/turnover). The samples excludes the *Power and Heat sectors*, as well as the *Cement sector in Hubei* which are subject to intensive targets. Robust standard-errors in parentheses. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

Figure B.1: Trends in Coal Consumption (2008-2014): ETS vs. non-ETS

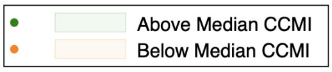


Notes. The figure plots year-specific treatment effects of the ETS on coal consumption separately for ETS firms (green) and unregulated firms (blue) against a 2010 baseline. The coefficient estimates are obtained from the interaction of the ETS regulation and unregulated dummies with year indicators in a fixed-effect panel regression where the dependent variable is coal use. Shaded areas represent 95% confidence intervals. Standard errors are clustered at the firm level.

Figure B.2: Trends in Energy Consumption (2008-2014): Robustness



(a) Coal (b) Oil (c) Electricity



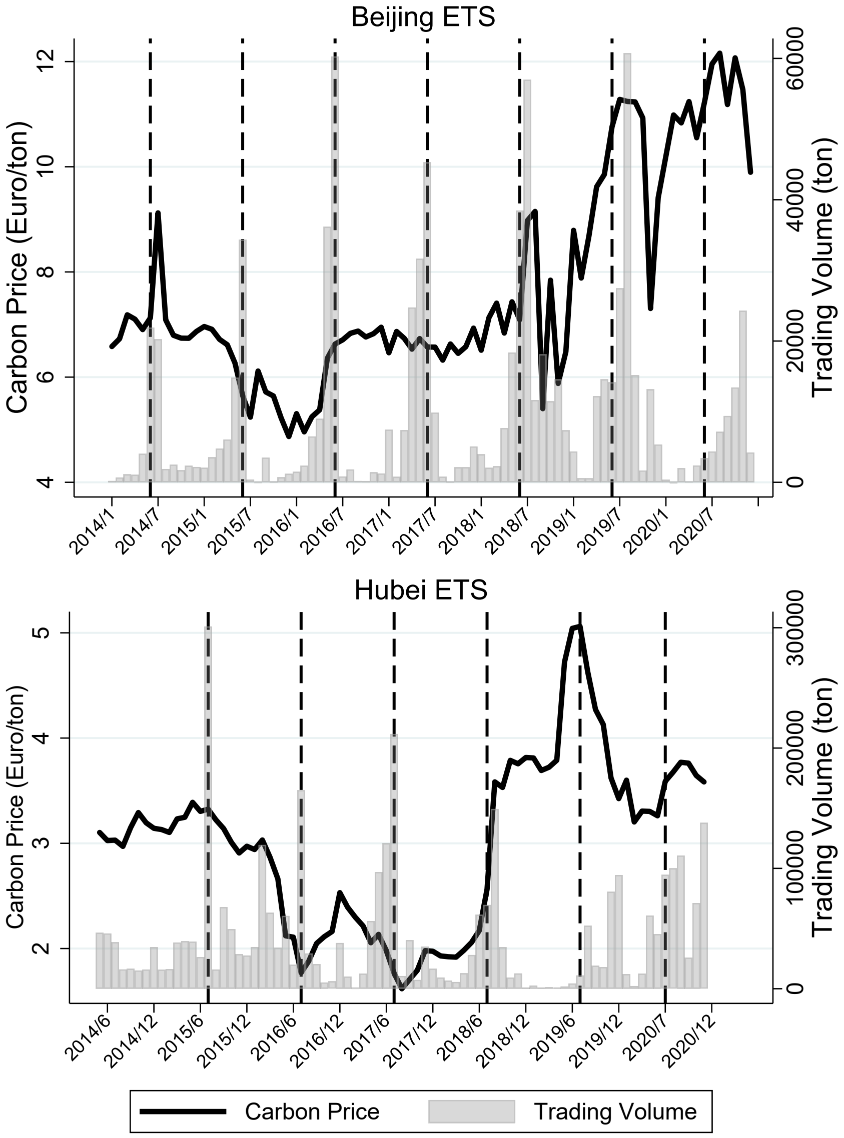
Notes. The figures plot year-specific treatment effects of the ETS on fuel consumption separately for firms with above-median CCM index (green) and the rest of the pack (red), relative to unregulated firms and against a 2010 baseline. Only observations with positive values of coal-consumption are included. The coefficient estimates are obtained from the interaction of the ETS regulation dummy, management tier, and year indicators in fixed-effect panel regressions where the dependent variable is coal use (panel a), oil use (panel b) and electricity use (panel c). All regressions control for year-by-region dummies. Shaded areas represent 95% confidence intervals. Standard errors are clustered at the firm level.

Table B.7: ETS Impact on Growth of Coal Use by CCMI Components: Robustness

	Dependent variable: ΔCoal						
Components:	Awareness	Energy use		GHG emissions		Target	Customer
		monitoring	target	monitoring	target	enforcement	pressure
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Median split							
ETS firm	-0.171	0.051	-0.237	-0.724	-0.003	-0.224	0.009
	(0.394)	(0.352)	(0.329)	(1.133)	(0.380)	(0.434)	(0.351)
Above-median component	0.149	0.851*	-0.006	0.444	0.819	-0.166	0.328
	(0.434)	(0.498)	(0.471)	(0.545)	(0.629)	(0.418)	(0.433)
×ETS firm	-0.287	-1.209*	-0.203	0.055	-1.169	-0.080	-0.720
	(0.571)	(0.617)	(0.610)	(1.249)	(0.736)	(0.568)	(0.568)
Number of firms	108	108	108	108	108	108	108
R^2	0.014	0.046	0.014	0.019	0.030	0.017	0.027
Adjusted R^2	-0.015	0.019	-0.015	-0.009	0.002	-0.012	-0.001
B. Quartile split							
ETS firm	-0.400	0.608	-0.233	-0.724	-0.003	0.340	0.009
	(0.592)	(0.535)	(0.468)	(1.133)	(0.380)	(0.636)	(0.351)
Above-25% component	-0.345	1.039**	-0.332	0.444	0.819	0.017	0.328
	(0.429)	(0.404)	(0.418)	(0.545)	(0.629)	(0.465)	(0.433)
× ETS firm	0.210	-1.429**	0.046	0.055	-1.169	-0.798	-0.720
	(0.680)	(0.626)	(0.593)	(1.249)	(0.736)	(0.708)	(0.568)
Number of firms	108	108	108	108	108	108	108
R^2	0.019	0.078	0.022	0.019	0.030	0.036	0.027
Adjusted R^2	-0.010	0.052	-0.007	-0.009	0.002	0.008	-0.001

Notes: OLS regressions include a constant (not reported). The dependent variables are the midpoint growth rates, as defined in eq. (3), for tons of coal. All regressions include *firm-level controls* and *interview 'noise' controls* as defined above. Robust standard errors in parenthesis are clustered at the firm level. Robust standard errors in parentheses. Significance levels are indicated as * 0.10, ** 0.05, *** 0.01.

Figure B.3: Historical prices and trading volumes in Beijing and Hubei



Notes: The graphs show monthly average prices and trading volumes based on data from Wind Economic Database, which covers over 1.3 million macroeconomic and industry time series data, such as financial markets, foreign trade, emissions trading markets, etc., in China. Prices were converted at a fixed currency exchange rate of 1 CNY = 0.13 Euro. The dashed lines indicate compliance cycles, which in Beijing end in June and in Hubei in July of each year.

C Questionnaire

C.1 Survey questionnaire

Questionnaire
A scoring guide was provided for the scores of 1, 3, and 5. Interviewers could award any integer score between 1 to 5.

Measuring Climate Change Management Practices
The objective was to capture climate change related management practices within firms. To summarize the vast amount of information from the survey and to mitigate the potential collinearity in responses, we compute scores for each topic I,II,III,… as simple averages of the scored answers to the specific sub-questions (a),(b),(c),… addressing this particular topic. We compute topical z-scores of those averages by subtracting the mean and dividing by the standard deviation. Broader indices such as the CCM Index are computed as unweighted averages of a subset of z-scores.

I. Awareness of pollution and climate change			
(a) How is pollution discussed within your business? Can you give examples? (b) Can you give examples of occurrences where pollution is formally discussed in management meetings? (c) Do your strategic objectives mention pollution? (d) Did you commission reports or studies on how pollution will affect your business? (e) Can you tell me how the discussion of management and strategic decisions about climate change differs from that about pollution? Can you give some examples?			
	Score 1	**Score 3**	**Score 5**
Scoring grid:	Don't know if threat or opportunity. No awareness.	Some awareness backed up by evidence that this is being formally discussed by management.	Evidence that climate change is an important part of the business strategy.
II. Energy control management			
(a) How detailed is your monitoring of energy usage? (b) How often do you monitor your energy usage? Since when? (c) Describe the system you have in place.			
	Score 1	**Score 3**	**Score 5**
Scoring grid:	No monitoring apart from looking at the energy bill	Evidence of energy monitoring as opposed to looking at the energy bill, i.e. there is some consciousness about the amount of energy being used as a business objective. However, discussions are irregular and not part of a structured process and are more frequent with price rises. Not more than quarterly monitoring of energy.	Energy use is measured and monitored constantly and is on the agenda in regular production meetings. Energy use in the plant is divided up in space (by production line, machine or similar) and monitored over time (daily, hourly or continuously). The amount of energy rather than the cost is focused on.
(a) Do you have any targets on energy consumption which management has to observe? (e.g. kWh of electricity) (b) Do you have an energy intensity (conservation) target? (c) Can you describe some of the challenges you face in meeting these targets? How often do you meet these targets? Do you think they are tough?			
	Score 1	**Score 3**	**Score 5**
Scoring grid:	No targets	Targets exist but seem easy to achieve	Evidence that targets are hard to achieve

III. GHG emissions and pollution management			
(a) Do you explicitly monitor your carbon emissions? Since when? (b) How do you estimate your carbon emissions? (c) Are your carbon estimates externally validated?			
	Score 1	**Score 3**	**Score 5**
Scoring grid:	No specific carbon monitoring.	Detailed energy monitoring with clear evidence for carbon accounting (at least firm level). Manager is aware that energy figures need to be scaled by carbon intensity.	Carbon accounting of both direct and indirect emissions (supply chain emissions). External validation of carbon figures.
(a) Do you have any absolute targets on carbon emissions which management has to observe? (b) How about any carbon emissions targets relative to your company's production of output? (c) Can you describe some of the challenges you face in meeting the targets? (d) How often do you meet these targets? Do you think they are tough? Note: If the manager replies they have pilot ETS targets, ask: Have these been translated into internal targets for management?			

	Score 1	Score 3	Score 5
Scoring grid:	No targets for carbon emissions.	There is some awareness of the contribution of different energy sources and production processes to carbon emissions, but this is a secondary consideration to cost focused energy targets. There is some degree of difficulty in the targets.	There are separate targets for carbon emissions, distinct from energy use. GHG emissions are a KPI (Key Performance Indicator) for the firm. The contribution of each energy source and the production process to GHG emissions is known and suggested improvement projects for the production are assessed on their potential impact on carbon as well as energy efficiency.

IV.	**Target enforcement**		
(a) What happens if energy consumption or GHG emission targets are not met? (b) Do you publicize targets and target achievement within the firm or to the public? Can you give examples? Are there financial consequences in case of non-achievement? (c) Are there non-financial consequences in case of non-achievement? (d) Is there a bonus for target achievement?			
	Score 1	**Score 3**	**Score 5**
Scoring grid:	No targets or missing targets do not trigger any response.	Both target achievement and non-achievement are internally and externally communicated.	Target non--achievement leads to financial consequences internally and/or externally; including penalties, e.g. staff does not get bonus.

V.	**Pressure from customers**		
(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? (d) Are your customers concerned about the standard of "green" management or production of your company? If so, to what extent?			
	Score 1	**Score 3**	**Score 5**
Scoring grid:	"B2C" - Not aware that emissions performance is of significant concern to consumers of their product. "B2B" - Not aware that businesses they supply to are concerned about the emissions of the plant; quality and price are the only considerations.	"B2C" - The business is aware of the importance of climate--change issues in general and so are conscious that their customers may consider GHG performance to be important, although they do not expect or require data as proof. "B2B" - Customers set ISO 14001 as a precondition to suppliers. Evidence of environmental compliance is requested, but details of emissions figures are not required.	"B2C" - Being seen to reduce GHG emissions is thought to be important in the purchasing decisions of the firm's consumers. This has been determined by market research or consumers have voiced their concern through other means. Customers also ask for certified data on emissions during production or usage. A customer--friendly system to recognize the best products in terms of energy efficiency is often available in the market (e.g. EU energy efficiency grade for home appliances). "B2B" - Customers ask for evidence of external validation of GHG figures. Customers request information on carbon emissions as part of their own supply chain carbon auditing. Customers conform to PAS 2050 or other national standard in carbon foot--printing and so require detailed information on a regular basis.

Carbon Market Behavior

The questions below focused on capturing the firm's understanding of and behavior in the pilot ETS. Questions under VIII refer to the nation-wide ETS (referred to as CCETS) which, at the time of the survey, was scheduled to begin in 2017.

VI.	**Rationality of market behavior**
(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?	

	Score 1	Score 3	Score 5
Scoring grid:	Take their permit allocation as a target to be met as such and do not take into account the price of permits or the cost of abatement. Just sell if there is a surplus or buy if there is a deficit.	Are in the process of learning how the market works and 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.	Company has a thorough understanding of the site-specific CO2 abatement cost curve. Trading is used as a tool to reduce compliance cost and to generate extra revenues from excess abatement. Moreover, company forms expectations about permit price and re-optimizes abatement choice if necessary. Trader resorts to futures and derivatives.

VII. Stringency of pilot ETS

(a) How tough is the emissions cap/quota currently imposed by the CCETS on your production site?
(b) Can you describe some of the measures you put in place to comply with the cap?
(c) How stringent has the enforcement been?
(d) What is the overall annual cost burden of being part of the pilot ETS?

	Score 1	Score 3	Score 5
Scoring grid:	Cap is at business as usual. No enforcement of cap.	Some adjustments seem to have taken place, however nothing which led to fundamental changes in practices; e.g. insulation, etc. The firm might be audited but this is rare / possibility to discuss with the auditor.	Measures which led to fundamental changes in production processes; e.g. fuel switching; replacement of essential plant and machinery. The firm's CO2 emissions are regularly audited (every year at least) by an independent third-party auditor.

VIII. Anticipated stringency of next ETS phase

(a) Do you expect to be part of the CCETS from 2017 onwards?
(b) How stringent do you expect the next phase of the ETS (from 2017 to 2020) to be?
(c) Will it be tough for your firm to reach such a target? Can you describe some of the measures you would have to put in place?
(d) Do you believe the allowances will be distributed through an auctioning mechanism?
(e) Is it likely that sanctions for non-compliance will become more stringent?
(f) Do you expect that the CCETS will be extended to a national trading market in the future?

	Score 1	Score 3	Score 5
Scoring grid:	Cap for next phase is anticipated to be comparable to business as usual. The manager believes there will be no additional sanctions and that they will receive the permits for free.	Phase II is likely to trigger some adjustments, however nothing that will lead to fundamental changes in practices. Only a small part of permits will be auctioned and sanctions are not expected to be very high.	The presence of strong sanctions, extensive use of auctioning and more stringent targets in Phase III is anticipated. It is likely to imply the adoption of measures which will lead to fundamental changes in production processes. It might also imply the closure of the plant, or redundancy of more than 20% of employment.

Measuring Green Innovation

The questions below refer to a firm's long-run strategy for environmental management. They gathered information about innovation efforts undertaken by the firm with the objective (i) to reduce emissions at their production facilities and (ii) to produce products that help customers to reduce their emissions.

IX. Process innovation

(a) Do you dedicate staff time and/or financial resources to finding new ways of reducing the GHG emissions at your facility? Did you commission any studies for that purpose?
(b) Can you give examples?
(c) What fraction of your firm's global Research & Development funds is used for that? (less than 10%, more than 10%?)

	Score 1	Score 3	Score 5
Scoring grid:	No R&D resources committed to reducing GHG emissions.	Evidence of R&D projects to reduce emissions	Evidence that this kind of R&D is an important component in the company's R&D portfolio

X. Product innovation

(a) Globally, is your company currently trying to develop new products that help your customers to reduce GHG emissions?
(Note: If the firm is not a multi-national company, then just asked about their entire firm's R&D plan)
(b) Can you give examples?
(c) What fraction of your Research & Development funds are used for that? (Less than 10%, more than 10%?)

	Score 1	Score 3	Score 5
Scoring grid:	No efforts to develop climate change related products	Some efforts but it is not the main objective of the firms R&D efforts	The firm is focusing all product R&D efforts on climate change

Questionnaire in Chinese

以下为采访问卷以及为采访员提供 1，3 和 5 得分的评分指南。采访员可以授予 1 到 5 之间的任何整数分数

I. 环境污染和气候变化的意识			
(a) 贵公司的员工是否会对环境污染进行讨论吗？能不能举出一些例子？ (b) 环境污染相关问题是否会在正式管理层会议讨论？能不能举出一些例子？ (c) 您公司是否有聘请专家顾问以便策划环境污染相关的战略目标？ (d) 关于环境污染的报告和学习将如何影响您的业务？			
	1 分	**3 分**	**5 分**
评分的指导标准:	不明白是威胁还是机会。	有证据说明在管理层被正式讨论过这个问题	有证据表明气候变化是商业策略中的重要的一部分。
II. 能源监管			
(a) 你们对于能源使用的监测能具体到什么程度? (b) 你们多久监测一次能量的使用？从什么时候开始？ (c) 描述下你们现有的系统。			
	1 分	**3 分**	**5 分**
评分的指导标准:	除了能源消费账单没有其它监控	不仅仅关注与能源账单，而是存在对能源使用量的监测，比如：存在作为经营目标能源的使用的意识。 然而，讨论是没有规律的，没有组织的，当价格上涨的时候会更加频繁。不超过一季一次的能源监控。	能源的使用会被不断地测量和监控，这也是定期会议的日常事项。空间上，能源的使用被分成在生产线上的，机器或者类似上的使用，能源使用每天，每小时或者连续地被监控）。关注能源使用量而不是费用。
(a) 你们在能源消耗上有什么目标（例如：多少千瓦时的）电量） (b) 你们公司是否有能源使用强度（保存）目标？ (c) 您能描述下为了达到这些目标前会有哪些挑战吗？多久一次能达到这些目标？您认为他们艰难吗？			
	1 分	**3 分**	**5 分**
评分的指导标准:	没有目标	目标存在但是很容易就能实现	证据表明目标很难实现。详细说明。
III. 温室气体排放与污染的监管			
(a) 你们有没有明确地监管你们碳排放量？从什么时候开始？ (b) 你们怎么估计碳排放量？ (c) 碳排放量的估计有没有经过外部的审核认证？			
	1 分	**3 分**	**5 分**
评分的指导标准:	没有特定的碳计量监控	详细的有明显证据的碳计量（至少在公司层面）的能源监控。经理意识到能源数据需要被碳强度衡量	直接和间接的排放（排放供应链）都需要计量碳的排放量。碳计量数据需要得到外部的验证
(a) 你们公司在碳排放上是否有什么绝对性的目标？ (b) 你们公司在碳排放上是否有什么相对于生产的排放目标？ (c)能不能描述下达到这些目标前会有哪些挑战 (d) 多久一次达到这些目标？你认为达到这些目标艰难吗？ 注：如果经理回答他们有碳排放交易这类型目标，问他们"这些目标是否已经变成管理层的内部目标了？"			
	1 分	**3 分**	**5 分**

评分的指导标准:	对于碳排放量没有目标	意识到不同的能源和生产过程会产生不同量的碳排放，但是相对于能源的成本来说这是个次要因素。实现目标有一定的难度	碳排放根据不同能源的使用具有不同的目标。温室气体碳排放量是公司的关键绩效指标。每种能源以及生产过程对碳排放量的影响是共识的，对碳以及能源效率的影响是用来评价生产项目的改善程度的。

IV. 目标的实施与严格性

(a) 如果能源消耗或者温室气体排放量的目标没有达到会发生什么
(b) 有没有在公司内部或者对公众宣传目标和目标的完成度？能给出例子吗？如果目标没有达成，会有财务上的后果吗？
(c) 如果没有达到目标, 是否会造成除了经济损失之外的其他后果?
(d) 完成目标会有奖金吗？

	Score 1	**Score 3**	**Score 5**
评分的指导标准:	没有目标或者没达标也不会导致任何后果	目标的完成和没有完成都会在公司的内部和外部得到宣传	没有完成目标会在公司内部或者外部导致财政上的后果；包括惩罚，例如，员工没有奖金

V. 公司面临顾客针对环境要求的压力

(a) 顾客关心你们温室气体排放量吗
(b) 他们是怎样表达这种关心的？
(c) 顾客需要你们公布二氧化碳排放量的数据吗？
(d) 你们的客户关心贵公司的绿色环保管理和产品吗？ 如果是的话，在何种程度上？

	1分	**3分**	**5分**
评分的指导标准:	B2C (面向终端顾客)顾客不认为排放量对于产品十分重要 B2B（面向其他商家），他们提供的交易没有考虑到产生的排放量；他们考虑的只有质量和价格	B2C（面对终端客户），企业意识到气候变化的重要性，他们的顾客也有可能认为温室气体排放量是很重要的，虽然他们并没有要求企业提供数据作为证据。 B2B（客户是其他商家） 客户对他们的供应商设置 ISO14001 作为前提. 环保达标的证据是需要的，但是具体的排放量数据不需要。	B2C（客户是终端用户） 降低 GHG 排放是公司的顾客做出购买决定的一个重要因素。市场的研究肯定了这个或者顾客通过其他途径表达了他们对于环境的关心。顾客也要求厂商提供在生产和使用当中排放量的有证数据。一个以客为尊的系统经常能在市场中识别出能源有效的产品。 B2B（客户是其他商家） 顾客要求 GHG 数据的外部检测结果。顾客需要碳排放的信息作为他们自己碳审计的供应链。顾客在碳排放量上遵守 PAS2050 或者其他国家标准，所以需要定期的具体信息。

碳排放交易的市场行为

VI. 公司企业在碳排放交易的市场行为与理智性

(a) 您如何决定购买，出售，或交易多少许可证？
(b) 在做出决定前，您是否有参考市场的能量价格以及/或者参考能量使用需求以便预测公司以后所需的碳排放的许可证？
（注：能源价格如石油，煤炭，天然气等的价格会影响能源的需求从而影响到碳排放额度的需求）
(c) 您公司是否有利用买卖碳排放的许可证以便抵销公司的减排成本？

	1分	**3分**	**5分**
评分的指导标准:	公司只以许可证的分配数量为目标，在碳排放上尽量不超过限额。在公司的营运操作不考虑排放许可证的价格或成本的减少。如果有盈余卖掉剩余的许可证。如果不够，则购买多些许可证。	公司现在正学习碳排放交易市场的过程中，现在已经有人在负责管理碳排放交易，以尽量减少排放成本。此人对金融市场的运作有经验，有时也会同生产经理进行合与作配合的探讨。	公司目前已经对整个二氧化碳减排成本有着透彻的了解。交易已经成为公司的一种工具来降低成本以达到官方的限额。此外，公司也会对碳排放市 场交易的价格进行预测。如果必要的话，公司也会对公司业务的需求而对 许可证的需求与价格重新评估，以达到对公司的最佳效益。我们的交易员也会利用期货及衍生工具来管理碳排放交易体系所分配的碳排放证限额。

VII. 碳排放交易试点的相关条例对公司企业的管制

(a) 目前碳排放交易所施加的排放上限/配额，对您公司生产活动的限制有多严格? (b) 请问您是否可以描述一些所采取的应对措施？ (c) 碳排放交易的强制施行有多严格？ (d) 请问您预计公司每年会因为碳排放交易体系所施加的政策而增加多少成本？			
	1分	**3分**	**5分**
评分的指导标准:	配额对公司没有任何影响.没有任何强制性	对公司有些影响，也采取了一些应对的调整与措施，但是没有导致根本性的变化，例如：更换隔离器，等。 公司可能会被监察审计，但是这很少见，或者； 公司管理人员可以和监察部门讨论其表现，或者； 公司经常性的被监察，但是重点不在CO_2排放	对公司有很大影响，导致根本性的变化。例如：转用燃料，更换重要的厂房及机器，等。 公司的CO_2排放指标经常性的被第三方监察机构监察（每年至少一次）
VIII. 公司对碳排放交易下一个阶段的展望与严格性			
(a) 你们预计会在2017年参与碳排放的交易吗？ (b) 你估计碳排放交易在下一个阶段（2017至2020）会有多严格的要求？ (c) 您的公司达到这样一个目标会是艰难的吗？你能描述一下你将采取的哪些措施？ (d) 你认为配额能通过拍卖机制分配吗？ (e) 您认为以后政府对不遵守条例的公司的惩罚会更加严厉吗? (f) 您认为碳排放交易会扩张到全国性的交易市场吗？			
	1分	**3分**	**5分**
评分的指导标准:	和平常一样没有更严格的要求。经理认为不会有附加的制裁而且他们会免费收到许可证。	第二阶段有可能引发一些调整，但是不会导致根本上的改变。只有一小部分许可证将被拍卖，制裁也不会非常严格。	第三阶段预测会有严格的制裁，广泛地使用拍卖，这些方法都会在生产过程中导致根本意义上变化。这也有可能意味着工厂的关闭或者大于百分之二十的裁员。

衡量绿色创新与科研发展

IX. 生产流程的创新与科研			
(a) 你们有没有使用员工时间和/或财政资源来寻找降低温室气体排放量的新办法？为了这个目的有没有展开研究？ (b) 能不能举一些出例子? (c) 你们公司全球研究发展资金的多少比例是用来达成这些目标的（少于10%，多于10%）？ (注：这不包括员工训练费用或者能源监控费用，应当是关于真正的创新的投入 。如果该家公司不是跨国企业，那就问他关于整个公司的研究发展计划)			
	1分	**3分**	**5分**
评分的指导标准:	没有资源投入针对减少温室气体排放的研发	证据表明有R&D项目来减少排放	这种类型的研发是公司R&D投资组合的重要组成部分
X. 产品的创新与科研			
(a) 在国际上，贵公司现在是否在研发帮助顾客减少温室气体排放量的新产品？ （注：如果该家公司不是跨国企业，那就问他关于整个公司的研究发展计划） (b) 能给出一些例子吗？ (c) 你们的研究和发展资金中的多少比例是用来研发这种新产品？（少于或者大于百分之十）			
	1分	**3分**	**5分**
评分的指导标准:	没有发展和环境变化有关的产品	有作出努力但是不是公司研究发展的主要目标	公司把所有研究发展产品的努力都放在了应付气候变化上