Strategic Management of Carbon Regulatory Pressure: Evidence from Public Firms in China

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Abstract

We examine how firms manage carbon-intensive activities by responding strategically to regulatory pressure. Using detailed carbon emissions data at both the headquarters- and establishment-levels in China, and a quasi-experimental rollout of carbon emission regulation implemented at the local level, we find that a listed firm reduces its overall carbon emissions by 44% when its headquarters is located within a pilot city. Further analysis reveals that the emission reductions come from two sources: establishment-level emission reduction and the divestment of regulated establishments. Establishment-level emission reductions come from reductions in output, with emission intensities of establishments unchanged. Moreover, significant emission leakage occurs, as output cuts at one regulated establishment are partially offset by increases in output at unregulated establishments of other firms. Divestments occur in cities where headquarters is regulated, but most are simply transferred to new owners rather than retired. There is no evidence of increased low-carbon innovation or the implementation of new firm-level environmental policies. Overall, the program appears to succeed in forcing large firms to cut output, thereby reducing emissions, but does not appear to drive improvements in efficiency.

Key words: Carbon Emissions, Regulatory Pressure, Divestment of Regulated Establishments, Emission Leakage

JEL Code: Q52, Q56, R52

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1. Introduction

In the age of global warming, carbon regulatory pressure has become prevalent, significantly impacting corporate operations around the world. Big corporations have significant operational scales and influence, therefore often face stringent regulations aimed at curbing their carbon emissions. Place-based policies, defined as strategic interventions targeting specific geographic areas to achieve local development goals by addressing their unique characteristics, have been widely applied in regulating carbon emissions (Barca et al., 2012; Giest, 2014). The question arises as to how firms respond to such regulatory challenges, which can influence their operational and strategic decisions. Using the setting of a place-based carbon emission regulation in China, and detailed data on headquarter and establishment-level emissions, we document how firms adopt strategic approaches to deal with regulatory pressure.

In the face of carbon regulatory pressure, firms could implement a variety of possible measures with different time horizons, including (1) they reduce their output, with a corresponding reduction in emissions; (2) they improve the operational efficiency of their establishments; (3) they switch to an existing technology that has lower emissions (e.g. recycle scrap steel in steel-making and upgrade equipment); and (4) they conduct research that would create low-carbon technologies (hence, receive low-carbon patents). Cutting production is a low-carbon strategy that immediately lowers emissions but at the cost of reduced economic output. Operational efficiencies require more time and may involve improved worker training, greater employee effort or learning by doing. Switching to existing low-emission technologies involves greater lead time and significant investment costs. Embarking on research for low-carbon technology is an innovation strategy that can only pay off in the medium or long run.

There is a substantial literature on how firms in developed countries manage their polluting activities under regulatory pressure, both at the level of individual facilities and at the level of the firm as a whole. Shapiro and Walker (2018) show that between 1990 and 2008 U.S. manufacturers in the aggregate achieved a 60% reduction in the six "criteria pollutants" (Lead, SO_2, NO_x, CO, ozone, and particulate matter) even as production increased, largely due to increasingly stringent federal regulation. The reductions were accomplished almost entirely through "decreases in pollution per unit of output within narrowly defined product categories" (p. 3817), suggesting that operational efficiencies and process innovation played important roles. Although the US lacks coherent federal policy on greenhouse gas (GHG) emissions, recent work finds that state and local financial incentive programs lead to significant facility-level reductions (Leffel et al., 2024). Even more modest forms of regulatory pressure, such as local community attitudes or mandatory emissions disclosure, can lead facilities to improve their operational efficiency by up to 7% for greenhouse gas emissions (Dowell and Lyon, 2024; Yang et al., 2021).

Another line of research warns that subnational regulations can cause "emissions leakage" to plants in unregulated jurisdictions, which can undercut the benefits of the policy (Fowlie, 2009). Even intra-firm emissions leakage may undercut some of the benefits of subnational regulation, because firms shift pollution within the firm from plants facing more stringent regulation to plants facing less stringent regulation (Gibson, 2019; Rijal and Khanna, 2020). The literature on leakage is reminiscent of the literature on the "pollution haven" effect, which suggests firms shift their heavily polluting operations to countries with weak standards. The empirical evidence on this hypothesis is mixed, with some studies finding little support (Eskeland and Harrison, 2003) but others finding that firms may offshore their pollution by importing products with greater associated emissions and shifting domestic plants to cleaner production activities (Li and Zhou, 2017). On the more positive side, environmental regulations also incentivize firms to carry out green innovation, especially when their polluting level or asset specificity is higher, with different policies driving different types of innovation (Berrone et al., 2013; Johnstone et al., 2010).

Developing countries often face constraints on institutional capacity that make environmental regulation less effective than in a developed-country context (Blackman et al., 2018). China is of particular interest because of its position as the largest emitter of GHGs, as well as for its recent emphasis on environmental improvement (Greenstone et al., 2021). Karplus et al. (2021) emphasize the labyrinthine nature of Chinese environmental regulation as well as the speed with which policies are abandoned and replaced with new ones, both features that create challenges for researchers seeking to measure the effects of certain policies. They note that many Chinese regulations target firm-level emissions intensity, so that overall pollution levels increase over time because rapid GDP growth overwhelms intensity improvements. The failure of the intensity approach to limit overall pollution has led to increased use of regional approaches targeting heavily polluted areas. The complexity of Chinese regulations, the fact that they target both the firm level and the regional level, and the frequency with which they are changed raises substantial risks that policies will fail to achieve their objectives. In addition to the need for overall assessment of policies, Karplus et al. (2021) call for further research into how heterogeneous firms respond to environmental regulations.

In this paper, we study a city-based program for reducing China's GHG emissions. In 2010, 82 cities designated as the first batch of low-carbon-zone pilots, followed by another 33 in 2013 and 45 in 2017. Pilot cities set emissions-reduction targets that are tougher than those set by the central government, and have some flexibility in how they achieve the targets. Firms, especially large ones headquartered in the city, are assigned targets, face inspections and risk financial penalties for violations. Cities may also restrict new entry, allowing only firms with low-carbon business plans. Some cities cap coal consumption or carbon emissions, which may require cuts in the output of carbon-intensive goods.

We find firms in pilot cities take two main approaches to reducing their total emissions. First, they cut production at establishments in these cities, with concomitant cuts in emissions. Second, they divest establishments in regulated cities, especially the ones with growing emissions levels. Both of these measures are costly for the firm, and they indicate the seriousness with which the city regulations are being implemented. At the same time, we found the program's efficiency low. Divestment has no impact on overall emissions, just on those emissions attributed to its owner. In addition, we found no reduction in emissions intensity, suggesting no operational efficiencies were achieved, nor any shifts to cleaner production mode or technology. Moreover, production is shifted to the firm's establishments in unregulated cities, indicating substantial emissions leakage. Such a set of outcomes might be considered effective for pollutants whose impacts create local "hot spots," but for global pollutants like GHGs, they suggest the policy is largely ineffective. Overall, the program appears to incentivize performative responses that reduce a firm's local emissions but have little impact on aggregate carbon emissions, carbon intensity, or low-carbon innovation.

2. Hypotheses

Headquarters play a crucial role in defining a firms' overarching mission and align diverse branches toward common strategic objectives, ensuring coherence across operating units (Gaba and Joseph, 2013). Headquarters centrally manage critical decision-making processes, such as resource allocation and risk mitigation, ensuring operational efficiency and consistent compliance with regulatory standards across all locations (Kostova et al., 2016).

Regulatory pressure from headquarters is a critical driver in overseeing carbon-intensive activities within public firms for several reasons. The regulatory environment in which a firm's headquarters operates often dictates corporate governance and strategic priorities, pushing firms to prioritize sustainability initiatives by setting emission reduction targets and implementing compliance mechanisms (Bansal, 2005; Delmas and Toffel, 2008). Additionally, the significant reputational risks associated with non-compliance can incentivize firms to adopt rigorous oversight to avoid legal penalties and damage to their brand image (Lyon and Maxwell, 2011). This regulatory pressure aligns with investor expectations, as many investors now incorporate environmental considerations into their decisions, creating an additional layer that encourages firms to demonstrate strong environmental performance (Clark et al., 2015). These factors collectively underscore the pivotal role of regulatory pressure from headquarters in shaping firms' environmental management strategies.

Hypothesis 1: The primary driver for managing carbon-intensive activities is regulatory pressure on headquarters.

Corporations often conduct their pollution-intensive activities at lower levels of the corporate hierarchy to buffer the parent company from pollution-related regulatory risks (Lee and Bansal, 2024). This is also validated in Table A1, which shows headquarters have a lower share of coal consumption and emission intensity. As a result, headquarters face pressing regulatory obligations and thus require their local establishments to actively reduce emissions to ensure compliance with environmental regulations and avoid legal penalties. In response to regulatory demands, firms often concentrate on closely regulating their local establishments. This strategic emphasis is driven by two main reasons. First, local carbon policies often prompt government officials to focus on reducing emissions within their jurisdictions, enabling them to easily apply and enforce regulations on firms in their vicinity. Second, the close physical proximity between headquarters and these local sites enables more efficient monitoring and management. Such proximity enhances communication, speeds up response times, and supports direct oversight, thus ensuring strict compliance with regulatory standards.

Hypothesis 2: Headquarters that face regulatory pressure mandate their local establishments to actively reduce emissions.

Emerging markets are characterized by high information unverifiability and law unenforceability (Luo, 2007). High information unverifiability means that reliable and accurate data about the market, such as firms' product mix and output value, is difficult to obtain. While firms are found to conduct excessive scanning and usage of personal information sources (Miller, 1987; Daft et al., 1988; Sawyerr, 1993), this also creates information challenge to regulators to contract on contingencies. As noted by Chen et al. (2024), although energy or carbon regulations in China aim to achieve the transition to sustainable production modes, due to the difficulties of monitoring firms' output, technology, and product mix, the actual regulations are mainly based on energy use or carbon emissions quotas. Firms may also be constrained by existing infrastructure and supply chains that are designed for current production modes, thus only take incremental sustainability strategies to reduce overall emissions (Hart & Dowell, 2011). Organizing rules for collaborative collective action were more effective for smaller scale issues (i.e., tailings ponds and water) than the larger scale issue (i.e., greenhouse gas emissions) (Bowen et al., 2018).

On the other hand, law unenforceability in emerging markets implies that even when legal frameworks exist, they may not be consistently applied or enforced. This can result in a business environment where contracts are not reliably upheld, intellectual property rights are vulnerable, and regulatory compliance can become unpredictable and burdensome (Nee, 1992; Delios and Henisz, 2000; Hoskisson et al., 2000). When complete enforceability on all firms is difficult, regulators tend to put more regulatory pressure on the big firms, while smaller firms are less regulated.

This leads to Hypothesis 3:

Hypothesis 3: When regulatory pressures are incomplete, firms respond strategically to regulations, causing emission leakage with limited transition to more sustainable production modes.

3. Policy Background

3.1 Background of the low-carbon-zone pilots

Many cities around the world are voluntarily devising low-carbon development plans.[5] China's local-level carbon emissions regulation, compared with other city-level plans, comes in a more centralized form. China's National Development and Reform Commission (NDRC) designated 82 cities as the first batch of low-carbon-zone pilots in 2010. In 2013 and 2017, 33 and 45 cities, respectively, were also designated low-carbon-zone pilots[6]. Figure A1 presents the geographical distribution of low-carbon-zone pilots.

The low-carbon-zone pilot program is widely considered one of the most important carbon emissions regulations in China (Zhang, 2015). The regulation also has the unique merit of incorporating 160 cities, covering above half of the total number of cities in China. Other carbon emission regulations generally only cover a few representative cities. Cities' achievements in low-carbon development are regularly examined by the NDRC.

3.2 Requirements and implementations of the low-carbon-zone pilots

After a review of cities' low-carbon development plans, we find that low-carbon cities take three main regulatory measures: increasing implicit emissions fees, preferential entry, and

5 Examples include https://www.globalcovenantofmayors.org/ (for global cities), https://www.epa.gov/statelocalenergy (for U.S. cities), and https://www.env.go.jp/en/earth/cc/2050_zero_carbon_cities_in_japan.html (for Japanese cities).

6 The lists of the three batches of pilots are available at China's government website: https://www.gov.cn/zwgk/2010-08/10/content_1675733.htm (1st batch); https://www.ccchina.org.cn/nDetail.aspx?newsId=28162\&TId=60 (2nd batch); https://www.gov.cn/xinwen/2017-01/24/content_5162933.htm (3rd batch).

production regulation. First, firms in cities designated as low-carbon pilots face an increase in implicit emissions fees. Pilot cities propose to inventory their emissions and set binding emissions-reduction targets that are tougher than the targets prescribed by the central government. Firms may face regular inspections and lose fiscal support if they are recognized as super-emitting firms. Regarding preferential entry, in some cities only firms with superior low-carbon technologies can enter the market. For example, Suzhou's low-carbon pilot plan specifies pre-approval of environmental protection, in which the environmental protection department intervenes in advance in the firm's registration process and forbids projects with high carbon emissions and environmental risks. Cities also set more detailed and specific entry policies, such as building near-zero carbon emissions zones where only zero-emitting firms can open. Production restriction also plays a role in regulatory measures. Some cities put a cap on total coal consumption or carbon emissions, which is achieved by lowering the total production of carbon-intensive goods. Large firms are particularly targeted in low-carbon policies, as cities' low-carbon development plans consistently state they plan to focus regulation on firms with high output, energy consumption, and carbon emissions. In some listed firms' annual reports, listed firms state they are asked to take the leading role in emission reduction in the face of the low-carbon-city pilots.

We find suggestive evidence that cities direct headquarters to regulate their associated establishments, especially the local ones located in the same city. Starting from 2010, listed firms are required to record and disclose the progress of emission reduction of their associated establishments[7]. This suggests the government's approach of managing headquarters and

[7] Available at: https://www.caep.org.cn/sy/zhxx/gh/201009/t20100915_624605.shtml.

establishments as a whole. We also find relevant newsletters indicating headquarters allocating emission-reduction responsibilities to the establishments by signing "Environmental Responsibility Agreement" with establishments[8]. Especially, in the cases of local low-carbon initiatives, we find when cities request listed firms to participate in the low-carbon transition, the associated establishments in the same city are asked to sign a side agreement pertaining to their emission reduction plans[9].

4. Methods

4.1 Data sources

We constructed our dataset by combining two major data sources: The China National Tax Survey Database (CNTSD) and the listed firm-headquarter-establishment mapping dataset.

The CNTSD is a large-scale annual survey conducted by China's Ministry of Finance and State Administration of Tax. The database documents operating activities of headquarters and establishments in China from 2008 to 2016. The dataset has the advantage of covering a larger number of establishments, compared to the Greenhouse Gas Reporting Program (GHGRP) in the US.[10]. The dataset has detailed information on establishments' energy consumption by

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8 Examples include: https://www.sohu.com/a/624923272_121383597;
https://mp.weixin.qq.com/s/4XDG6_N_rCDPitdje4ipbQ;
https://mp.weixin.qq.com/s/SfXkiR7kCwtLE31B9m5yUA;
https://mp.weixin.qq.com/s/_2XWLlxsZcAyxyDczD7KZQ.

9 The case is between Nanjing city government and a large public firm in renewable energy called Contemporary Amperex Technology Co. Limited (CATL). The Nanjing City Government signed a strategic cooperation agreement with CATL to launch comprehensive strategic cooperation around the construction of a "zero-carbon city". During the same occasion, CATL's subsidiaries then signed relevant cooperation agreements. The case is available at: https://www.catl.com/news/7978.html.

10 After data cleaning, the CNTSD covers 240,000 establishments per year. GHGRP covers 7,544 establishments in 2023 (available at: EPA Facility Level GHG Emissions Data).

source, including coal, oil, and electricity, which is used to calculate carbon emissions. We follow the methods by Cui et al. (2021) to process the CNTSD. Our data cleaning excludes the following observations: (1) Observations with negative values for total assets, fixed assets, and total output; (2) Observations with negative, missing, or anomalous values (specifically, a value of one) for energy consumption; and (3) Observations exhibiting changes in headquarter/establishment-level carbon emissions exceeding 500% over two years.

To identify the mapping relationship between headquarters and establishments from CNTSD, we use the listed firm-headquarter-establishment mapping dataset from the Chinese Research Data Services Platform (CNRDS). The listed firm-headquarter-establishment mapping dataset from CNRDS (hereafter referred to as CNRDS) lists all establishments of each listed firm in each year using information disclosed in the firms' annual reports. The disclosed information is further cross-verified with establishment ownership information from the National Enterprise Credit Information Publicity System. We match the mapping of headquarter and establishment from CNRDS with CNTSD using both IDs and names. The matched dataset contains the relevant information of the headquarters and their corresponding establishments during 2008-2016.

4.2 Sample

The first step to construct our sample is matching the CNTSD and CNRDS. In our baseline sample, we define the associated establishments of the listed firms as all the associated and subsidiary establishments. Our robustness check uses alternative ways to define associated establishments and shows that the results are still robust. After matching, we exclude listed firms receiving a delisting warning or in the financial sector. The final matched dataset has 36,606 observations, with 78% of observations being establishments and 22% being headquarters. We then aggregate the matched establishment and headquarter level data to listed firm-year level. In our baseline sample, we have 6,431 observations covering 1,258 distinct listed firms. Table A1 reports the carbon emissions and energy structure of the headquarters and subsidiaries. As Table A1 shows, establishments have almost twice the emissions per unit of output compared to headquarters. Establishments also have a higher coal consumption ratio. Headquarters are larger (with higher total direct and indirect emissions) and with higher electricity consumption ratio. These statistics indicate that establishments are central to emission-intensive activities, while headquarters primarily function as corporate administrative centers.

4.3 Dependent variable

The dependent variable is listed firm-level carbon emissions. Carbon emissions incorporate both direct and indirect carbon emissions. The direct carbon emissions are from combustion of fossil fuels, while the indirect carbon emissions come from the consumption of purchased electricity. For each listed firm, we calculate carbon emissions by multiplying the consumption of each energy type (i.e., coal, oil, and electricity) by its carbon emission factor[11.] Energy consumption is measured in metric tons of standard coal equivalent (TCE)[12.]

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[11] Ideally, natural gas consumption is also used in calculating direct carbon emissions. However, natural gas consumption is not included in the dataset and accounts for less than 5% of direct carbon emissions in recent years.

[12] According to the suggestions by IPCC (2006), the emission factor for coal, oil, and electricity are respectively 1.89kg CO_2/kg, 3.02kg CO_2/kg, and 7.5kg CO_2/kWh.

4.4 Independent variables

The main independent variable is the regulatory status of the headquarter. We define the regulatory status equaling to 1 if the headquarter is regulated under low-carbon-pilot policy and after the policy is implemented. The regulatory status equals to 0 otherwise. We use the headquarters' regulatory status as the main independent variable because headquarters oversee the whole listed firms' operation. We further use other measures of regulatory status in subsequent analysis, including the share of local establishments, headquarter and local establishments both regulated, only headquarter regulated, and only establishment regulated, and compare the emission-reduction effects of these regulatory status to the null status—headquarter and establishments all unregulated.

4.5 Control variables

4.5.1 Firm characteristics

We control for the following firm-level financial characteristics: Total assets, tangible asset ratio (tangible asset/total asset), return on assets (net profit/total asset), book-to-market ratio (book value/market value), leverage (total debt/EBITDA), and dummy for SOE (state-owned enterprises). Firm-level financial data are from the China Stock Market and Accounting Research Database (CSMAR).

4.5.2 City characteristics

City characteristics are added to the empirical specification to control for the selection criteria of low-carbon-city pilots. The Chinese government clarified the selection criteria for low-carbon pilots as socioeconomic conditions and geographical layout. Given that the first batch of low-carbon-city pilots was implemented in 2010, we control for the key socioeconomic variables prior to policy implementation to control for the confounding factors of policy implementation. Specifically, we include key socioeconomic factors that may determine policy implementation, including log per capita GDP, log population, and relative GDP rank in the province in 2009, all interacting with linear year trend.

4.6 Statistical estimation

The main empirical strategy used in the empirical analysis is difference-in-differences (DD). We start with the following econometric specification at the listed firm level:

$$log(Emissions_{ict}) = \alpha + \beta 1(HQ\ Reg_{ct}) + Firm\ Controls_{it} + City\ Controls_{ct} \times Linear\ Trend + \lambda_c + \lambda_t + \varepsilon_{ict} \quad (1)$$

where *i*=firm, *c*=city, *t*=year. *Emissions* is the carbon emission at the listed firm level, i.e., the summed emissions of the headquarter and associated establishments. Emissions are calculated from the consumption of coal, oil, and electricity. The coal and oil emission factors are calculated according to the IPCC guidelines, taken as 1.89 $kgCO_2/kg$ and 3.02 $kgCO_2/kg$, respectively. Electricity emission factors are derived from the National Center for Climate Change Strategy and International Cooperation, taken as 0.8843 $kgCO_2/kWh$, 0.7769 kgCO2/kWh, 0.7035 kgCO2/kWh, 0.5257 kgCO2/kWh, 0.6671 kgCO2/kWh, 0.52711 kgCO2/kWh for North China, Northeast China, East China, Central China, Northwest China, and Southern China power grids, respectively.

1 (*HQ Reg*) takes the value of 1 if the listed firm's headquarters is located in a low-carbon

city pilot and the year is after the pilot policy implementation; otherwise, it is 0. The coefficient β estimates the difference in the average carbon emissions between the treated group (firms regulated under low-carbon-city pilot) and the control group (firms not exposed to the regulation) before and after the treatment, while controlling for firm and year fixed effects. ε_{ict} is the error term. Firm fixed effects and year fixed effects are included.

To understand how headquarters regulation affects a conglomerate's total carbon emissions, we separately estimate its effects on headquarters and establishments. The empirical specification for headquarter level analysis is the same as Equation (1), except that we replace the outcome variable from overall firm to headquarter level carbon emissions. In the establishment-level analysis, we replace the outcome variable with establishment-level carbon emissions, and also change the main independent variable to 1(*Est Reg*). 1(*Est Reg*) takes the values of 1 if the establishment is located in a low-carbon city pilot and the year is after the pilot implementation.

We also include the joint regulatory status of headquarters and establishments in the regression to unpack their respective roles in managing carbon-intensive activities. We define a variable, *Local Est Share*, equaling to the share of the firm's establishments that are in the same city as headquarters, and interact it with the regulatory status of headquarters, 1(*HQ Reg*), in firm-level and headquarters-level emission analysis.

In establishment-level analysis, we define the following joint regulatory status: 1(*HQ & Local Est Reg*), 1(*HQ and Nonlocal Est Reg*), 1(*Only HQ Reg*), and 1(*Only Est Reg*). Specifically, 1(*HQ & Local Est Reg*)=1 when the establishment is regulated and its headquarter is regulated and located within the same city; 1(*HQ and Nonlocal Est Reg*)=1 when the establishment is regulated and its headquarter is regulated but located in a different city; 1(*Only HQ Reg*)=1 when the establishment is not regulated but the headquarter is regulated. 1(*Only Est Reg*)=1 when the establishment is regulated but the headquarter is not regulated.

Note that we want to have a "stable" control group that is not subject to any kind of regulation. Therefore, the control group includes listed firms that do not face any headquarter or establishment-level treatment through our sample period. Table 1 presents the summary statistics.

5. Results

5.1 Baseline results

Table 2 presents the baseline regression results. All columns use direct and indirect carbon emissions as the outcome variable. As Table 2 shows, in all three specifications, the coefficients on 1(*HQ Reg*)=1 are all significantly negative at the 1% level, indicating that firms headquartered in a low-carbon-city pilot policy significantly reduce their carbon emissions. Column (3) has a coefficient of -0.572, suggesting that if the headquarter of a listed firm faces carbon emissions regulation, the listed firm reduces total carbon emissions by a very impressive 44%. Overall, the results suggest that the primary driver for emission reduction is regulatory pressure on headquarters, validating Hypothesis 1.

5.2 Event study analysis

We then move to test pre-treatment parallel trends for the pilot cities (i.e., treatment group) and non-pilot cities (i.e., control group). The event study takes the following form:

$$Emissions_{ict} = \alpha + \sum_{k=-5,k\neq-1}^{k=5} \beta_k 1(HQ\ Reg_c) \times Time_{ct-k} + Firm\ Controls_{it} +$$

$$City\ Controls_{ct} \times Linear\ Trend + \lambda_c + \lambda_t + \varepsilon_{ict} \qquad (2)$$

where $1(HQ\ Reg)$=1 when the headquarters is in the low-carbon-city pilot. $Time_{ct-k}$=1 if the year is k years after the regulation starts, with k=-1 omitted to avoid multi-collinearity. Figure 1 presents the results of our event-study analysis. As Figure 1 shows, prior to the regulation, there are no persistent pre-trends in firms' carbon emission levels. After the regulation, the coefficients are consistently negative. Coefficients for Year=0 and Year=+2 are significant at the 5% level. Overall, the results suggest our findings are not driven by pre-trends.

5.3 Robustness checks

Next, we detail the robustness checks used in this paper. All the results are shown in Table 3. First, recent literature suggests that having different treatment timings would lead to biased estimates under the circumstances of heterogeneous treatment effects. We implement a stacked difference-in-differences design that compares establishments affected by low-carbon-city pilots with not-yet-treated ones. Specifically, we use a stacked DID regression similar to Cengiz et al. (2019). The stacked DID estimator constructs separate cohorts based on treatment timing and uses a corresponding control group made up of never or late-treated units for every cohort. All the cohorts are then stacked together by variance weighting to construct the combined treatment effects. Column (1) is the stacked difference-in-differences estimation results, which are qualitatively similar to our baseline results.

Second, we cluster the standard errors in different ways and check if the results are consistent. Column (2) clusters the standard errors at city level and Column (3) two-way clusters the standard errors at city and sector level. The results suggest our baseline results still hold with different ways of clustering. Third, to deal with the concern that our results may be driven by some industrial trends, Column (4) replaces year fixed effects with year-sector fixed effects and yields similar results. Finally, Columns (5) and (6) use different ways to define associated establishments, respectively as all the subsidiaries with a shareholding ratio≥ 50% and all the first and second tier subsidiaries. The results still show that the carbon emissions are significantly reduced when the headquarter is regulated.

5.4 Delving into different regulatory statuses

We further examine how different types of regulatory status affect carbon emissions. We classify regulatory status into different types, based on whether headquarter and and/or establishments are regulated under the low-carbon-city pilot. Column (1) of Table 4 interacts 1(*HQ Reg*) with *Local Est Share*, where *Local Est Share* denotes the share of the number of the firm's establishments located in the same city as the headquarter. As illustrated in Column (1), the coefficient for 1(*HQ Reg*)×*Local Est Share* is significant and negative, whereas 1(*HQ Reg*) alone has an insignificant coefficient once the interaction term with *Local Est Share* is included. This indicates that the impact of the low-carbon-city pilot is significant only when a firm has local establishments. Moreover, the effect intensifies as the proportion of the number of local establishments to all establishments increases. Column (2) of Table 4 shows the effects of 1(*HQ & Local Est Reg*), i.e., both having the headquarter and (at least one) establishment regulated. The results in Column (2) suggest that having both headquarter and establishment regulated have a large and significantly negative coefficient of -0.578, implying an 8.67% (0.578/6.664) emission reduction. Overall, the results suggest headquarters that face regulatory pressure mandate their local establishments to actively reduce emissions, validating Hypothesis 2.

Column (3) of Table 4 shows the firm-level emission effects of 1(*Only Est Reg*), equaling to 1 when headquarter is not regulated but (at least one) establishments are regulated. The results in Columns (3) suggest that only having establishments regulated leads to a significant increase in direct and indirect emissions at the firm level. Because the coefficient on log emissions is .417, this suggests that firm-level emissions rose by roughly 51%. This could result from emission leakage from regulated establishments to other unregulated ones, as was found in the context of U.S. firms' criteria pollutant emissions by Gibson (2019). We further examine the emission leakage hypothesis using establishment- level data. We define the treatment type of 1(*Only Other Est Reg*), which equals to 1 when the establishment and headquarter are unregulated, but at least one other establishment in the listed firm is regulated. The results in Columns (1) and (3) of Table A3 suggest having other establishments in the listed firm regulated (while headquarters and the establishment are unregulated) leads to an increase in establishment-level emissions of roughly 31%. Although there is a slight drop of emissions in the regulated establishments, as Columns (2) and (4) of Table A3 show, the drop is small and statistically insignificant. In sum, the establishment-level results in Table A3 support the emission leakage story.

6 Potential channels

6.1 Headquarter and establishment-level emission reduction

We then examine the channels of listed firm-level emission reduction. First, since previous results already show that a significant emission reduction occurs at the listed firm level, we further examine where the listed firms' emission reduction comes from, whether it is from headquarters or associated establishments. Table 5 presents the effects of low-carbon-city pilot status on headquarters' emissions. Columns (1)-(4) of Table 5 consistently show that none of the regulatory statuses affects emissions at headquarters. Column (2) of Table 5 also suggests that the interaction between the headquarters' regulatory status and the share of the number of local establishments has null effect. This may be because headquarters are generally cleaner and do not have the potential or urgency to carry out more emission reduction.

Table 6 examines how the low-carbon-city pilot affects establishment-level emissions. In Column (1) of Table 6, we find the regulatory status of headquarters has a large and significantly negative effect on associated establishments' emissions. Moreover, when we delve into different regulatory types, we find the negative effects are only significant with the regulatory status 1(*Local Est & HQ Reg*). This suggests headquarters are requiring their associated local establishments to cut their emissions. On the contrary, no significant emission reduction is observed for establishments with regulatory status of 1(*Nonlocal Est & HQ Reg*) (i.e., headquarter and this establishment both treated, but in different cities).

We further analyze where the emission reduction comes from. Changes in emissions can be decomposed into two factors, scale effect and technique effect as follows (Shapiro and Walker, 2018):

$$\frac{dC}{C} = \frac{dY}{Y} + \frac{de}{e} \tag{3}$$

where C denotes the total carbon emissions, Y is the level of output, and e is the emission intensity (i.e., emissions per unit of output). An increase in efficiency (in other words, a decrease in emissions per unit of output) and a decrease in output may both lead to emission reduction. To examine which of the two factors plays a dominant role in establishments' emission reduction, we respectively regress emission intensity and output on the implementation of a low-carbon-city pilot. The results in Table 7 suggest that only the coefficient on output is significantly negative. This suggests establishments mainly reduce their emissions by reducing output level, instead of increasing emission efficiency.

6.2 Divesting regulated establishments

Other than emission reduction of establishments, another source of emission reduction is that listed firms may divest the establishments subject to regulatory pressure. We examine the divesting behavior using the headquarter-establishment mapping dataset from CNRDS. In Table 8, Columns (1)-(4) suggest the low-carbon-city pilot increases both the number and registry capital of divested establishments. Table 9 further separates the divested establishments into different types: (1) the ones in cities where headquarters are located; (2) the ones in other low-carbon-city pilots; and (3) the ones not in low-carbon-city pilots. The results for the three types are respectively shown in Columns (1)-(2), (3)-(4), and (5)-(6). We find only the establishments in cities where headquarters are located are divested after the headquarter faces the regulation. We further investigate the fate of the divested establishments and find that only 7% exit the market. The remaining establishments continue to operate, either as stand-alone entities or under the ownership of other non-listed companies. In Table A4, we further use establishment-level data and examine if establishments with higher emissions are more likely to exit. The outcome variable is a dummy variable, equaling to 1 if the establishment is divested.

The results suggest that establishments with higher carbon emissions are indeed more likely to exit. Thus, divestment could potentially be seen as a punishment for establishments that fail to reduce their emissions.

6.3 Further analysis: What else do corporates do?

In this section, we further examine if firms respond to low-carbon-city pilots in other ways. We use the following four outcomes: The number of low-carbon patent applications, the number of corporate environmental policies, environmental (E) score, and environmental, social, and governance (ESG) score.

The first measure is the number of low-carbon patent applications the firm (i.e., headquarter and all the establishments) applies for in a given year. The definition of low-carbon patents is from the website of the International Patent Classification (IPC) Green Inventory. We obtain the patent code of each patent applied by the firms and match it with the codes for low-carbon patents provided by the IPC Green Inventory. The results in Column (1) of Table 10 suggest that the policy has an insignificant effect on the number of low-carbon patent applications. Column (2) of Table 10 examines the effects on the conduct of corporate environmental policies. The number of corporate environmental policies is the number of environmental policies mentioned in the firms' annual reports and social responsibility reports. We conduct textual analysis to all the reports and extract if the firm has implemented environmental policies. The list of environmental policies we analyze include: environmental protection concept, environmental protection goal, environmental protection management system, regular environmental protection education or training, environmental protection special act, environmental event emergency mechanism, environmental protection honor and reward, and the simultaneous system between production and pollution reduction facilities. Given that each of the environmental policies is only carried out in a small number of firms, we use a dummy variable to indicate the conduct of corporate environmental policies, equaling to 1 if the corporate has implemented any of the above-mentioned environmental policies. The dummy variable of the conduct of environmental policies has a mean of 0.4449. Columns (3) and (4) of Table 10 respectively show the effects of the regulation on corporates' E score and ESG score. The scores are all retrieved from Bloomberg. The results suggest that the low-carbon-city pilot is not conducive to the improve in corporates' E and ESG scores. Combining the results in Table 10 and Table 7, the low-carbon-city pilot does not help decrease corporate emission intensity, nor does it increase green innovation, conduct of corporate environmental policies, or firms' environmental and ESG performance in general. This suggests corporates do not transit to cleaner production modes following the increase in regulatory pressure, validating Hypothesis 3.

7. Conclusions

Our study reveals how listed firms in China manage carbon-intensive activities by strategically responding to regulatory pressure. Analyzing detailed carbon emissions data at both headquarters and establishment levels, we find that overall carbon emissions are reduced only when headquarters faces carbon regulatory pressure. This reduction originates from two primary actions: establishment-level emission reduction and divestment of local establishments. Specifically, establishment-level emissions are reduced only when the establishment is located in the same city as the headquarters, primarily through output reduction, while emission intensities remain unchanged. Second, firms respond by divesting regulated establishments in the same cities, especially those with high emissions, allowing these establishments to operate independently or be purchased by other, non-listed firms. Importantly, we observed no significant enhancement in green transition activities such as heightened green innovation or improved environmental policies at the headquarters level.

Although listed firms achieve emissions reduction, the sources of these emissions are to a large extent transferred rather than eliminated. To the extent they are reduced, this comes at the cost of proportionate reductions in output rather than efficiency improvements. This phenomenon highlights the market-level spillover effects of regulatory pressure. Our findings underscore the intricate dynamics at play in developing countries, where a volatile information environment may prompt firms to handle regulatory demands in ways that could inadvertently exacerbate environmental issues.

The findings also have implications for ESG disclosure policies. Establishing clear corporate standards that encompass all legal entities is crucial to prevent an organization from facing litigation risks stemming from subsidiaries' inadequate ESG performance. ESG disclosures should be structured to encompass both the headquarters and their associated entities.

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Figures and Tables

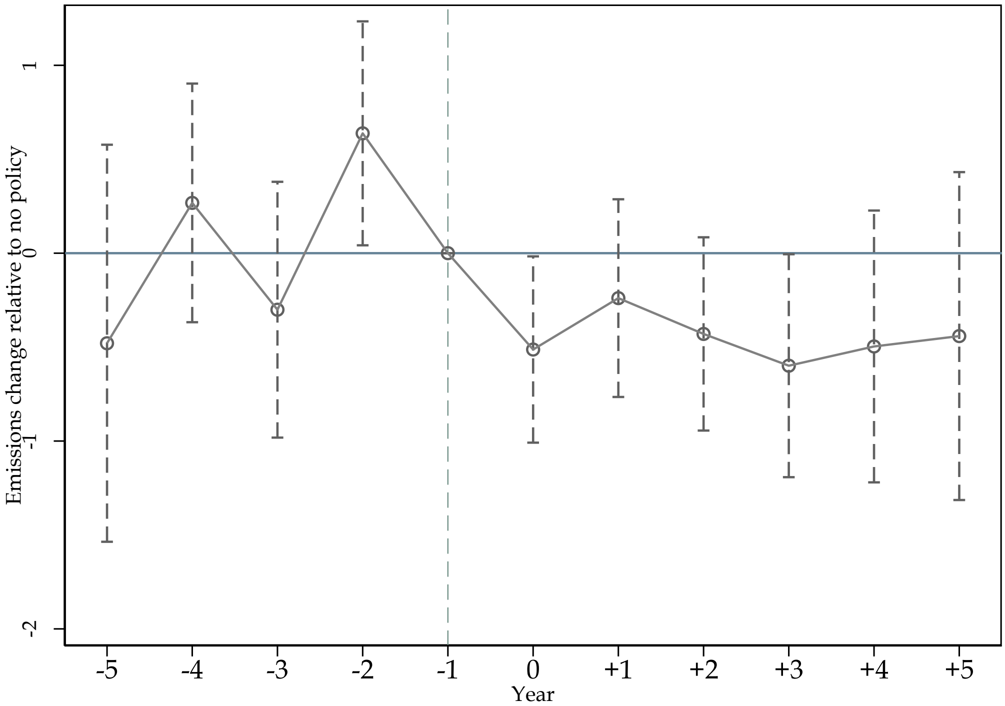

Figure 1. Event-study analysis

Notes: This figure is the event study analysis for direct and indirect carbon emissions following Equation (2), controlling for log per capita real GDP, log population of the cities (all interacted with linear trend), and firm and year fixed effects. The vertical line around each plotted coefficient indicates the 95% confidence interval, with standard errors clustered at firm level.

Table 1: Summary statistics

Variable	Mean	SD	Min	Max
Outcome variables				
Direct carbon emissions	4.1167	4.2547	0	15.12
Direct and indirect carbon emissions	7.2292	4.0219	0	15.861
Key independent variables				
1(HQ Reg)	0.3302	0.4703	0	1
City-level controls				
GDP_2009	4851.605	4167.848	100.5957	13123.07
Pop_2009	756.5114	513.1726	27.6	3275.61
Rank_2009	6760.361	7215.127	2008	42273
Firm-level controls				
Total_assets	22.122	1.3888	16.5844	28.5087
Tangible asset ratio	0.9396	0.0762	0.1649	1
Return on assets	0.0516	0.069	-1.0939	1.4488
Book-to-market ratio	0.6324	0.2305	0.0171	1.363
Leverage	0.4725	0.43	0.0108	18.9398
SOE	0.4772	0.4995	0	1

Notes: Carbon emissions (log) are calculated from the consumption of coal, oil, and electricity. Key independent variables are regulatory status of headquarter and (or) establishments. City-level controls are GDP per capita, population, and relative GDP rank within the province in 2009 interacted with year dummies. The firm-level controls are calculated as follows: Total assets (log), tangible asset ratio (tangible asset/total asset), return on assets (net profit/total asset), book-to-market ratio (book value/market value), leverage (total debt/EBITDA), and dummy for SOE (state-owned enterprises).

Table 2. Baseline results

	(1)	(2)	(3)
	Direct and indirect carbon emissions		
1(HQ Reg)	-0.542***	-0.553***	-0.572***
	(0.162)	(0.161)	(0.160)
Total assets		0.314**	0.301**
		(0.150)	(0.151)
Tangible asset ratio		-0.627	-0.577
		(1.031)	(1.046)
Return on assets		-1.464	-1.357
		(0.942)	(0.943)
Book-to-market ratio		-0.0529	-0.0533
		(0.401)	(0.400)
Leverage		-0.168	-0.202
		(0.234)	(0.238)
SOE		-0.371	-0.368
		(0.372)	(0.374)
City-level controls*Linear trend			Y
Firm FE	Y	Y	Y
Year FE	Y	Y	Y
N	6431	6431	6431
R-sq	0.618	0.619	0.623

Notes: All models show OLS regressions with standard errors clustered at firm level. Standard errors are reported in parenthesis. City-level controls include GDP per capita, population, and relative GDP rank within the province in 2009.

Table 3. Robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)
1(HQ Reg)	-0.427***	-0.597**	-0.597**	-0.708***	-0.724***	-0.688***
	(0.152)	(0.277)	(0.260)	(0.180)	(0.195)	(0.225)
Total assets	0.270**	0.295	0.295	0.303*	0.434*	0.434*
	(0.116)	(0.200)	(0.180)	(0.161)	(0.230)	(0.248)
Tangible asset	-0.716	-0.666	-0.666	-0.430	-0.253	-1.936
ratio	(0.850)	(1.537)	(1.384)	(1.089)	(1.234)	(1.426)
Return on assets	-1.688**	-0.825	-0.825	-0.702	-3.081**	-1.569
	(0.765)	(0.930)	(0.866)	(1.064)	(1.241)	(1.550)
Book-to-market	0.215	0.134	0.134	0.143	-0.0653	-0.243
ratio	(0.308)	(0.396)	(0.416)	(0.458)	(0.507)	(0.573)
Leverage	0.187	-0.338	-0.338	-0.315	-0.791	0.0159
	(0.244)	(0.268)	(0.207)	(0.268)	(0.686)	(0.873)
SOE	-0.354	-0.363	-0.363	-0.246	-0.389	-0.351
	(0.310)	(0.522)	(0.527)	(0.382)	(0.503)	(0.562)
City-level controls*Linear trend	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	N	Y	Y
Year-Sector FE	N	N	N	Y	N	N
Cluster	Firm	City	City and sector	Firm	Firm	Firm
N	7449	6431	6431	6331	4582	6167
R-sq	0.627	0.623	0.623	0.660	0.624	0.608

Notes: Column (1) is the stacked difference-in-differences estimation results. Column (2) clusters the standard errors at city level. Column (3) two-way clusters the standard errors at city and sector level. Column (4) replaces year fixed effects with year-sector fixed effects. Column (5) defines a listed firm as the parent firm and all the subsidiaries with shareholding ratio≥ 50%. Column (6) defines a listed firm as the parent firm and all the first and second tier subsidiaries. Standard errors are reported in parenthesis. City-level controls include GDP per capita, population, and relative GDP rank within the province in 2009.

Table 4. Effects of different regulatory categories on public firm-level emission reduction

	(1)	(2)	(3)
		Direct and indirect emissions	
1(HQ Reg)	-0.303		
	(0.205)		
1(HQ Reg)*Local Est Share	-0.855*		
	(0.456)		
1(HQ & Local Est Reg)		-0.578***	
		(0.160)	
1(Only Est Reg)			0.417***
			(0.152)
Total assets	0.285**	0.302**	0.161
	(0.127)	(0.151)	(0.174)
Tangible asset ratio	-0.529	-0.580	-2.118*
	(0.891)	(1.046)	(1.176)
Return on assets	-1.320	-1.339	-1.554
	(0.989)	(0.943)	(1.111)
Book-to-market ratio	-0.0612	-0.0337	0.366
	(0.364)	(0.402)	(0.450)
Leverage	-0.206	-0.206	0.779
	(0.262)	(0.238)	(0.610)
SOE	-0.375	-0.369	-0.422
	(0.385)	(0.374)	(0.448)
City-level controls*Linear trend	Y	Y	Y
Headquarter FE	Y	Y	Y
Year FE	Y	Y	Y
N	6431	6424	5856
R-sq	0.622	0.623	0.611

Notes: All models show OLS regressions with standard errors clustered at headquarter level. Standard errors are reported in parenthesis. City-level controls include GDP per capita, population, and relative GDP rank within the province in 2009.

Table 5. Effects on headquarters

	(1)	(2)	(3)	(4)
	Direct and indirect emissions			
1(HQ Reg)	-0.234	-0.515		
	(0.349)	(0.489)		
1(HQ Reg)*Local Est Share		0.876		
		(1.184)		
1(HQ & Local Est Reg)			-0.243	
			(0.359)	
1(Only Est Reg)				-0.384
				(0.563)
Total assets	-0.123	-0.116	-0.130	-0.501
	(0.330)	(0.330)	(0.334)	(0.427)
Tangible asset ratio	0.793	0.693	0.712	0.753
	(2.223)	(2.216)	(2.277)	(3.061)
Return on assets	-1.122	-1.083	-1.419	-1.006
	(2.560)	(2.571)	(2.622)	(3.680)
Book-to-market ratio	-0.636	-0.651	-0.677	1.139
	(0.958)	(0.957)	(0.982)	(1.170)
Leverage	0.937	0.981	0.831	-1.059
	(1.182)	(1.177)	(1.197)	(1.320)
SOE	1.155	1.173	1.168	-1.914*
	(1.082)	(1.083)	(1.080)	(1.021)
City-level controls*Linear trend	Y	Y	Y	Y
Headquarter FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	2794	2794	2707	1954
R-sq	0.770	0.770	0.769	0.775

Notes: All models show OLS regressions with standard errors clustered at headquarter level. Standard errors are reported in parenthesis. City-level controls include GDP per capita, population, and relative GDP rank within the province in 2009.

Table 6. Effects on associated establishments

	(1)	(2)	(3)	(4)	(5)
	Direct and indirect emissions				
1(HQ Reg)	-0.598***				
	(0.152)				
1(Local Est & HQ Reg)		-0.617***			
		(0.207)			
1(Nonlocal Est & HQ Reg)			0.0499		
			(0.218)		
1(Only HQ Reg)				-0.225	
				(0.243)	
1(Only Est Reg)					-0.456
					(0.319)
Total assets	0.113	0.0754	0.0190	0.125	0.0575
	(0.102)	(0.124)	(0.122)	(0.139)	(0.163)
Tangible asset ratio	-0.360	-0.808	-1.259	-0.848	-0.943
	(1.275)	(1.571)	(1.442)	(1.621)	(1.777)
Return on assets	0.563	-0.302	0.0203	-0.336	-0.796
	(1.159)	(1.342)	(1.422)	(1.451)	(1.560)
Book-to-market ratio	0.0539	0.166	0.462	0.174	0.532
	(0.417)	(0.500)	(0.509)	(0.530)	(0.555)
Leverage	0.624	0.188	0.758	0.0446	0.416
	(0.535)	(0.619)	(0.632)	(0.678)	(0.691)
SOE	-0.591*	-0.657	-0.0856	-0.355	-0.326
	(0.353)	(0.436)	(0.370)	(0.425)	(0.509)
City-level controls*Linear trend	Y	Y	Y	Y	Y
Establishment FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
N	20971	16068	14596	13875	12790
R-sq	0.793	0.787	0.805	0.813	0.812

Notes: All models show OLS regressions with standard errors clustered at city-establishment level. Standard errors are reported in parenthesis. City-level controls include GDP per capita, population, and relative GDP rank within the province in 2009.

Table 7. More analysis on associated establishments: Output reduction or efficiency increase?

	(1)	(2)	(3)	(4)
	Direct and indirect emissions/output		Output	
1(HQ Reg)	1.310	1.321	-0.567***	-0.571***
	(1.019)	(1.024)	(0.0847)	(0.0846)
Total assets	-0.868	-0.870	0.126**	0.129**
	(0.615)	(0.615)	(0.0570)	(0.0567)
Tangible asset ratio	-0.862	-0.860	-0.00880	-0.0303
	(3.816)	(3.816)	(0.612)	(0.613)
Return on assets	2.875	2.878	1.835***	1.818***
	(2.000)	(2.001)	(0.636)	(0.637)
Book-to-market ratio	1.379	1.381	-0.0120	-0.0144
	(1.165)	(1.166)	(0.211)	(0.211)
Leverage	0.774	0.778	0.202	0.205
	(0.930)	(0.929)	(0.290)	(0.291)
SOE	0.213	0.217	-0.0543	-0.0536
	(0.386)	(0.386)	(0.194)	(0.193)
City-level controls*Linear trend	Y	Y	Y	Y
Establishment FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	20868	20868	20495	20495
R-sq	0.310	0.310	0.723	0.724

Notes: All models show OLS regressions with standard errors clustered at city-establishment level. Standard errors are reported in parenthesis. City-level controls include GDP per capita, population, and relative GDP rank within the province in 2009.

Table 8. Effects on divestment

	(1)	(2)	(3)	(4)
	Number of divested establishments		Registry capital of divested establishments	
1(HQ Reg)	0.0407*	0.0607***	0.268*	0.442***
	(0.0209)	(0.0222)	(0.147)	(0.156)
Total assets	0.105***	0.104***	0.625***	0.615***
	(0.0198)	(0.0199)	(0.131)	(0.131)
Tangible asset ratio	-0.247**	-0.241**	-1.873***	-1.796***
	(0.0982)	(0.0982)	(0.656)	(0.656)
Return on assets	-0.922***	-0.910***	-5.680***	-5.587***
	(0.186)	(0.186)	(1.112)	(1.108)
Book-to-market ratio	-0.233***	-0.230***	-1.280***	-1.249***
	(0.0494)	(0.0494)	(0.344)	(0.344)
Leverage	0.0791	0.0859	0.813**	0.855**
	(0.0560)	(0.0560)	(0.411)	(0.411)
SOE	-0.0520	-0.0560	-0.214	-0.254
	(0.0570)	(0.0575)	(0.378)	(0.384)
City-level controls*Linear trend		Y		Y
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	10258	10235	10258	10235
R-sq	0.374	0.374	0.354	0.354

Notes: All models show OLS regressions with standard errors clustered at firm level. Standard errors are reported in parenthesis. City-level controls include GDP per capita, population, and relative GDP rank within the province in 2009.

Table 9. Effects on divestment: More analysis

	(1) # of divested establish-ments in cities where HQ is located	(2) K of divested establish-ments in cities where HQ is located	(3) # of divested establish-ments in other low-carbon city pilots	(4) K of divested establish-ments in other low-carbon-city pilots	(5) # of divested establish-ments not in low-carbon city pilots	(6) K of divested establish-ments not in low-carbon city pilots
1(HQ Reg)	0.063***	0.443***	0.011	0.065	0.00874	0.160
	(0.016)	(0.124)	(0.014)	(0.112)	(0.0130)	(0.102)
Total assets	0.0374***	0.283***	0.0662***	0.467***	0.0522***	0.331***
	(0.0126)	(0.0992)	(0.0136)	(0.0936)	(0.0131)	(0.101)
Tangible asset ratio	-0.0958	-0.794	-0.112*	-0.807*	-0.0458	-0.605
	(0.0671)	(0.522)	(0.0669)	(0.483)	(0.0534)	(0.467)
Return on assets	-0.446***	-3.168***	-0.575***	-3.876***	-0.328***	-2.405***
	(0.131)	(0.927)	(0.138)	(0.818)	(0.119)	(0.782)
Book-to-market ratio	-0.125***	-0.782***	-0.144***	-0.983***	-0.0678**	-0.523**
	(0.0349)	(0.270)	(0.0317)	(0.242)	(0.0311)	(0.251)
Leverage	0.0289	0.239	0.0152	0.187	0.0324	0.189
	(0.0395)	(0.323)	(0.0327)	(0.277)	(0.0331)	(0.290)
SOE	0.0178	-0.126	-0.0300	-0.0379	-0.0230	0.180
	(0.0388)	(0.297)	(0.0379)	(0.253)	(0.0297)	(0.256)
City-level controls*Linear trend	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	10258	10235	10258	10235	10258	10235
R-sq	0.340	0.320	0.340	0.307	0.300	0.294

Notes: All models show OLS regressions with standard errors clustered at firm level. Standard errors are reported in parenthesis. "#" and "K" respectively denote number and registry capital. City-level controls include GDP per capita, population, and relative GDP rank within the province in 2009.

Table 10. Effects on firms' environmental governance

	(1) Number of low-carbon patent applications	(2) Conduct of corporate environmental policies	(3) E score	(4) ESG score
1(HQ Reg)	-0.0199	-0.0319	-0.00188	-0.00259
	(0.0695)	(0.0677)	(0.00389)	(0.0154)
Total assets	0.476***	0.242***	0.00917***	0.0211*
	(0.061)	(0.0531)	(0.00323)	(0.0125)
Tangible asset ratio	-0.426	0.572*	0.0617***	0.00868
	(0.353)	(0.309)	(0.02)	(0.0752)
Return on assets	0.311	0.0725	-0.0308	-0.0246
	(0.38)	(0.378)	(0.0227)	(0.0812)
Book-to-market ratio	0.181	0.368***	0.0330***	0.0391
	(0.152)	(0.143)	(0.00822)	(0.0299)
Leverage	0.0478***	0.0545***	-0.0205**	-0.0164
	(0.00979)	(0.0113)	(0.00994)	(0.0479)
SOE	0.279	-0.242	0.00485	-0.0145
	(0.171)	(0.162)	(0.00779)	(0.0477)
City-level controls*Linear trend	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	15249	15249	12541	12541
R-sq	0.632	0.583	0.694	0.658

Notes: All models show OLS regressions with standard errors clustered at firm level. Standard errors are reported in parenthesis. City-level controls include GDP per capita, population, and relative GDP rank within the province in 2009.

Appendix

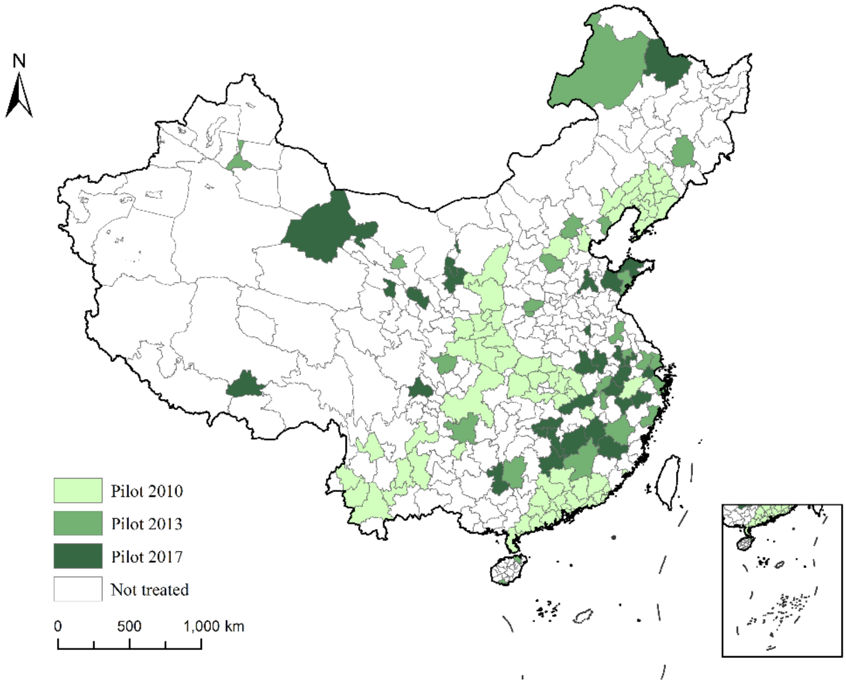

Figure A1. Geographical distribution of pilot cities

Table A1. Comparison of headquarters and establishments

	Headquarters	Establishments
Avg. share of energy consumption from coal	16.95%	17.54%
Avg. share of energy consumption from oil	14.49%	14.19%
Avg. share of energy consumption from electricity	68.56%	68.28%
Direct and indirect emissions per unit of output (ton/CNY)	0.492	0.869
Direct and indirect emissions (ton)	32500.08	24239.66
Number	2218	11141

Table A2: Summary statistics of different regulatory status

Regulatory status	Percentage
Share of firms with 1(*HQ Reg*) ever =1 through all years	26.91%
Share of firms with 1(*HQ & Local Est Reg*) ever =1 through all years	49.61%
Share of firms with 1(*Only HQ Reg*) ever =1 through all years	0.86%
Share of firms with 1(*Only Est Reg*) ever =1 through all years	43.14%
Share of firms do not face any headquarter or establishment regulation through all years	18.64%

Table A3. Evidence of emission leakage within the listed firms

	(1)	(2)	(3)	(4)
	Direct and indirect carbon emissions			
1(Only Other Est Reg)	0.292**		0.271*	
	(0.143)		(0.145)	
1(Only Est Reg)		-0.144		-0.115
		(0.160)		(0.163)
Total assets			0.625**	0.642**
			(0.265)	(0.265)
Tangible asset ratio			2.280	2.220
			(1.834)	(1.834)
Return on assets			5.722**	5.596**
			(2.501)	(2.501)
Book-to-market ratio			-0.0764	-0.0979
			(0.600)	(0.600)
Leverage			1.992**	1.962**
			(0.950)	(0.950)
SOE			-0.685	-0.685
			(0.768)	(0.768)
City-level controls*Linear trend	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	8834	8834	8515	8515
R-sq	0.421	0.421	0.426	0.426

Table A4. Exit and establishment-level carbon emissions

	(1)	(2)
	Dummy of exit	
Direct and indirect carbon emissions	0.000925**	0.000680*
	(0.000397)	(0.000408)
Total assets		0.0117***
		(0.00389)
Tangible asset ratio		-0.000946
		(0.0460)
Return on assets		-0.0523*
		(0.0292)
Book-to-market ratio		0.0302***
		(0.0111)
Leverage		0.00845
		(0.0194)
SOE		0.0433***
		(0.0159)
Establishment FE	Y	Y
Year FE	Y	Y
N	28010	26751
R-sq	0.587	0.596