# The Real Effects of China's Carbon Dioxide Emissions Trading Program

Xiangzhen Li* Hao Wang†

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**JEL Classification**: H23; L51; Q52; Q58C

**Keywords**: investment, employment, productivity, real wage, state-owned enterprises.

*School of Economics and Management, Tsinghua University. Email: lixz22@mails.tsinghua.edu.cn.

†School of Economics and Management, Tsinghua University. Email: wanghao@sem.tsinghua.edu.cn.

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China's emissions trading system applies a salient two-stage emissions intensity-based compliance quota allocation scheme significantly different from the cap-and-trade systems prevalent in developed economies. It was designed to accommodate the country's socioeconomic complexities and implemented following a learning-by-doing approach. Compliance firms increased green investment and expanded production workforce, while their climate decisions are influenced by state ownership and regional heterogeneity. State-owned enterprises (SOEs) and firms in regions with less liberal markets increased hiring, but not investment; non-SOEs and firms in more liberal markets expanded investment only. Compliance firms maintained productivity and operating efficiency; however, ordinary workers' real wages were reduced, more prominent in SOEs..

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# 1 Introduction

China's emissions trading system (ETS) is the world's largest carbon market by emissions volume coverage and the first established in an emerging economy. It currently applies a salient two-stage emissions intensity-based compliance quota allocation scheme different from the cap-and-trade systems prevalent in developed economies.[1] The program was designed to accommodate China's socioeconomic complexities: weak legal framework, diverse institutional characteristics, income disparity, industrial heterogeneity, and continuously evolving climate policies (Duan and Zhou, 2017; Goulder et al., 2017; Karplus and Zhang, 2017). Implementation of the ETS follows a learning-by-doing approach, so continued assessment, review, and modification of the program are critically important.

This paper investigates how China's ETS affects firms' real decisions and economic welfare during its initial implementation and assesses to what extent it has achieved the goal of evoking climate awareness and changing emitting behaviors. We construct a comprehensive firm-level data set and develop a staggered difference-in-difference (DiD) model to gauge the following compelling questions to policymakers, compliance entities, and other stakeholders: how did the emissions trading program affect firm investment and employment decisions? How did the effects interact with key institutional characteristics? What are the implications for economic welfare? Answers to these questions help assess China's ETS and provide references for the other emerging economies that plan to implement their emissions trading programs.

We find that firms significantly increased capital expenditure and research and development (R&D) inputs in response to compliance coverage. On average, a compliance firm had 16.53% higher investment, equivalent to 86.12 million yuan, than a non-compliance firm. A further investigation classifies investment projects into five categories: carbon neutrality, natural

[1] Emissions intensity is measured as the ratio of carbon emissions to production output. In this sense, the intensity-based program does not limit the quantity of carbon emissions to a compliance firm in the initial stage. See Section 2 for more details. In contrast, the cap-and-trade program imposes a strict limit on the quantity of carbon emissions and reduces that limit over time to reach a pollution target. As the limit decreases each year, it reduces carbon emissions to the limit set by regulation. Entities that exceed their emissions quota must buy unused quotas from other companies or face penalties. Policymakers hint that China's ETS may switch to the cap-and-trade approach when it is more mature.

gas-related, environment protection, retrofit, and others. It shows that investment in the "carbon neutrality" projects is positively and significantly associated with compliance coverage, while the others are not. The finding implies that firms responded to ETS coverage with more investment in carbon-efficient projects and, at the same time, maintained investment in other projects. The pattern echoes Zhu et al. (2019) and Cao et al. (2021) that compliance firms increased innovation inputs in carbon-efficient technologies and shifted production to low-emissions facilities without actively shutting off less efficient ones. China's ETS's intensity-based compliance quota allocation scheme subsidizes carbon-efficient firms for greater production, and *ex ante* stimulates green investment. On the other hand, establishing a clear and enforceable emissions target is important to achieve further efficiency gain and greater abatement.

The compliance firms, on average, hired 327 more employees, about 6.72% of their entire workforce, than the non-compliance firms. A more detailed analysis classifies employees into five categories: low-skilled production workers, high-skilled production workers, sale personnel, administration staff, and R&D personnel. It shows that the numbers of production workers and R&D personnel are positively correlated with compliance coverage, while the number of administration staff is negatively correlated, indicating that the compliance firms not only expanded employment but also adjusted workforce composition.

Firm climate decisions are influenced by state ownership and regional heterogeneity. State-owned enterprises (SOEs) and firms in regions with less liberal markets hired more employees but did not expand investment. In contrast, non-SOEs and firms in more liberal markets grew investment only. Chinese governments promote "green employment." SOEs are regarded as a major source of job creation, and firms in the regions with less liberal markets are more prone to government influence. On the investment side, the prices of strategic products and services, e.g., electricity and natural gas, are not market-determined but administered in China. SOEs that dominate these sectors have relatively weak incentives to reduce emissions as they cannot pass the costs to consumers. Market dominance enables SOEs to pass abatement burden to other firms along the supply chain, and political connection increases the difficulty for regulation to impose non-compliance penalty.[2] The findings highlight that government agenda and economic distortions could overshadow this market-oriented program, and that institutional reforms in a broader context are needed to remove barriers.

Benefits to productivity and wages are mixed. At the firm level, productivity proxied by total factor productivity (TFP), operating efficiency proxied by revenue per capita, and value creation proxied by Tobin's Q are not significantly correlated with compliance coverage. A positive way to interpret the results is that the ETS did not cause adverse productivity and efficiency shocks. However, compliance firms pay lower real wages to non-executive employees, which is more prominent in SOEs. Liu, Tan, and Zhang (2021) find that China's pollution control policy significantly reduced labor demand and that low-skilled employees were more affected. Shrunk compensation could reduce morale and work quality and subsequently damage the climate program. It implies that corporate governance, a key component of the Environmental-Social-Governance (ESG) system, plays an important role in facilitating the emissions abatement program to achieve environmental gains in a balanced and sustainable manner.

This research gains insight into the emissions trading program pioneered by an emerging economy. As an alternative to the cap-and-trade programs adopted by the developed economies, the ETS sacrifices cost-effectiveness for flexibility and compatibility with the country's institutional structure (Goulder and Morgenstern, 2018; Goulder et al., 2022). The program encouraged firms to take action without causing abrupt productivity shocks. Its subsidy to firms with higher carbon efficiency incentivized green investment. Intensity-based emissions compliance allows firms to increase (decrease) output during an economic expansion (contraction), mitigating their fear about economic and climate policy uncertainties. The program is also compatible with the country's environmental policies, mostly emissions intensity-based. China's ETS faces challenges in emissions measurement, reporting and verification, liquid trading and fair pricing, and compliance supervision. The initial success

[2] About 97% of green bonds, whose issuance is subject to high eligibility requirements and stringent approval, were issued by SOEs. Most government climate subsidies have eligibility requirements on, e.g., firm size and profitability, which rule out most non-SOEs.

gained momentum to battle these challenges. It provides an example to the other emerging economies facing socioeconomic complexities in designing their emissions trading programs.

Our research adds to the burgeoning literature on China's carbon program.[3] This paper first examines real decisions in concert with institutional characteristics. Real decisions lead to real effects. Our findings help interpret the phenomena documented in previous works besides complementing them. The research sheds the first light on the welfare effects of China's ETS. It demonstrates that structural distortions embedded in the economy could undermine the effectiveness of this market-oriented program. The significant presence of SOEs and politically driven agenda add challenges to the ETS, highlighting the importance of broader reforms to remove barriers during the in-depth implementation stage.

The remainder of this paper is organized as follows. Section 2 reviews China's ETS. Section 3 presents our empirical methodology and data. Section 4 analyzes the empirical findings. Section 5 conducts robustness checks. Section 6 concludes the paper.

# 2 China's Emissions Trading Program

This section reviews China's ETS to set the stage for our empirical analysis. It follows the chronological order to describe the regional pilot programs followed by the national market.

## 2.1 The Regional Pilots

After signing the United Nations Framework Convention on Climate Change in 1992, China gradually transited to a low-carbon development pathway. The government chose to establish an emissions trading system over carbon taxation, considering that the market-based approach would give companies greater autonomy in determining how to achieve their emissions targets. Other considerations include the country's socioeconomic complexities, possible economic

[3]Among others, Cui et al. (2018) and Zhu et al. (2019) find that China's pilot emissions trading programs induced carbon innovation. Gallagher et al. (2019) use a mixed-method methodology to analyze the likelihood of Chinese climate policies reducing greenhouse gas emissions following China's Paris commitments. Cao et al. (2021) examine the production behaviors of firms in the regulated electricity sector. Recently, Cui et al. (2021) study firm tax records and find that implementing China's pilot ETSs reduces carbon emissions despite low carbon prices and infrequent trading.

impacts, and continuously evolving policy environment. As for the past policies, China adopted a learning-by-doing approach to establish some pilot programs first and then the national program after gaining experiences from the pilots.

In September 2010, the State Council released *The Decision on Accelerating Cultivation and Development of Strategic Emerging Industries*, proposing to establish carbon emissions trading system. In the following year, the National Development and Reform Commission (NDRC), the government planning organization responsible for climate policy, announced *The Notice on the Implementation of Pilot Carbon Emissions Trading Systems*.[4] Seven regional pilots were established in five cities (Beijing, Shanghai, Tianjin, Chongqing, and Shenzhen) and two provinces (Guangdong and Hubei). Selection of the pilots aimed to reflect China's industrial and geographic heterogeneity and income disparities. It also considered the region's economic development, institutional characteristics, and enterprise concentration. The pilot programs were implemented in 2013 and 2014.[5]

[Insert Table 4 here.]

While establishing the pilot programs was a state policy, implementation and operation went to the regions. As a result, the pilots have different industry coverage, inclusion standards, and allowance allocation mechanisms, reflecting the regional economic situations. They cover important industries in the regions besides heavy industries.[6] For example, as a transportation hub, Shanghai includes commercial buildings, railways, ports, airports, and aviation; Beijing includes hotels, universities, and medical facilities. The inclusion standards are also different; for example, the inclusion threshold is 3,000 $tCO_2$ equivalence in Shenzhen, 5,000 in Beijing, 20,000 in Shanghai, Guangdong, Tianjin, and Chongqing, and 10,000 metric

[4] After institutional reform of the State Council in 2018, governance of the ETS was transferred from NDRC to the Ministry of Ecology and Environment.

[5] The Shenzhen pilot began on June 18, 2013, followed by Shanghai on November 26, 2013, Beijing on November 28, 2013, Guangdong on December 13, 2013, Tianjin on December 26, 2013, Hubei on April 2, 2014, and Chongqing on June 19, 2014. Two unofficial ETSs were implemented in the provinces of Fujian and Sichuan in 2016. We do not include these unofficial markets in this study because of their unofficial nature and relatively small sizes.

[6] Heavy industries include electricity and heat generation, cement, petrochemicals, iron and steel, nonferrous metals, pulp and paper, and glass.

tons of standard coal equivalence consumption in Hubei. Each year, the pilots publish their compliance firms lists. The firms contribute 40% to 60% of the total carbon emissions in the regions.

A salient feature of the regional pilot programs is that they apply a two-stage allowance allocation scheme significantly different from the traditional cap-and-trade scheme. At the beginning of a compliance period, firms receive a fraction (typically 60%) of the allowance based on their (or sector's) historical emissions, following the "grandfather" rule; at the end of the compliance period, firms obtain the rest of the allowances according to their actual outputs. In other words, the emissions allowances are finally determined when outputs are observed at the end of the compliance period. At the time of this writing, nearly 95% of the emissions allowances are allocated for free, and 3% to 10% of the budgeted allowances are reserved for auction.[7]

## 2.2 The National Market

The regional pilots constitute experiments and preparation for the national ETS officially launched in July 2021. When complete, the national market aims to cover 7,000 entities and the country's 70% carbon dioxide emissions. It covers only the electricity industry at the initial (current) stage. There are 2,162 entities with annual carbon emissions exceeding 26,000 $tCO_2e$; most are power generators. These firms' total carbon emission volume is over 4.5 billion tons of $CO_2e$ per year, nearly 40% of the country's total emissions (Cao, Ho, Ma, and Teng, 2021).

Allocation of emissions allowance, initially free, also follows the two-stage intensity-based scheme, which offers flexibility to an emerging economy with fast-growing power demand and continuously evolving climate policy (Pizer and Zhang, 2018; Goulder, Long, Lu, and Morgenstern, 2022). Pragmatism is heavily valued. As a result of trading off the economic and institutional complexities, the scheme is not the first-best cost-effective and is subject to future modification. According to Duan and Zhou (2017), the most important objective of

[7] See Cui, Wang, Zhang, and Zheng (2021) for a review of the allowance allocation schemes.

China's ETS in the initial implementation is to evoke firms' climate awareness and stimulate abatement action.

Unlike the regional pilots that disclosed their coverage and implementation rules right before market opening, the national market published an incremental development plan in *The Work Plan for the Construction of the National Carbon Emissions Trading System (Power Sector)* in December 2017, four years before the launch. The feature demands careful treatment of the expectation effect in research.

In summary, the development of China's ETS is still in an early stage. Table 2 shows that the trading volume ranged between 0.39 and 27 million metric tons of $CO_2$ for the regional pilots and 178 million tons for the national market in 2021, less than 5% of the total allowance quota allocated to the compliance firms. The carbon prices vary significantly across markets, with the highest of USD 9.48 in Beijing and the lowest of USD 1.74 in Shenzhen, considerably lower than the average carbon price of EURO 20 for the European Union ETS (Bayer and Aklin, 2020).

# 3 Empirical Methodology

This section describes our empirical methodology. It starts with the model, followed by the data and key variables.

## 3.1 The Model

We develop a staggered DiD model to study the real effects of China's ETS. A merit of the model is mitigating the confounding effects of other synchronous energy and environment policies (Pang and Duan, 2016; Karplus and Zhang, 2017; Baker, Larcker, and Wang, 2022; de Chaisemartin and D'Haultfoeuille, 2022). The treated group includes domestically listed compliance firms covered by national and regional programs. The list of compliance firms changed each year, and the number of firms increased over time, providing a quasi-natural experimental setting. The control group includes listed firms in the compliance industries but not covered by the ETS. Focusing on compliance industries increases the comparability between the treatment and control firms.

The baseline DiD model is expressed as

$$Decision_{i,t} = \beta ETS_{i,t} + \gamma Controls_{i,t} + \epsilon_{i,t}, \tag{1}$$

where $Decision_{it}$ denotes real decisions of firm $i$ observed at the end of year $t$; $ETS_{it}$ is a dummy variable that equals one if firm $i$ is covered by the ETS in year $t$ and zero otherwise. $Controls_{i,t}$ represents a set of control variables of firm $i$ observed at the end of year $t$. Section 3.3 presents the variables. We also include the decision variables lagged by one period and control the firm-, year-province- and year-industry-fixed effects for latent factors.

The DiD estimator has an important parallel trends assumption; that is, in the absence of treatment, the treated and control groups should have the same evolution patterns. To verify this assumption, we conduct an event-study estimation using pre- and post-treatment ETS dummy variables to compare the treated and control firms' decisions before and after the ETS coverage. In particular, we estimate the following regression model:

$$Decision_{i,t} = \sum_{j=2}^{m} \beta_j ETS_{i,t-j} + \sum_{k=0}^{n} \beta_k ETS_{i,t+k} + \gamma Controls_{i,t} + \epsilon_{i,t}, \tag{2}$$

where $j$ represents the $j$th pre-treatment year, and $k$ represents the $k$th post-treatment year. We use $j$ and $k$ up to six; that is, six years before and after the ETS coverage. Figure 1 depicts the parallel trends assumption test results for investment and employment. The evidence indicates that there are no significant differences between the decisions of the treated and control firms before compliance coverage, but their decisions significantly departed after it. The parallel trends assumption appears intact, and the staggered DiD model is compatible with the data. Section 5 provides additional robustness checks.

[Insert Figure 1 here.]

## 3.2 Data

Unlike previous research that usually identifies ETS coverage by sector or region, we construct a comprehensive firm-level data set.[8] The raw data contains compliance firm names and social credit numbers. An obstacle is that most of the entities covered by the regional pilots are the subsidiaries or branch offices of listed firms. We match the original 23,594 entity-ETS-year observations to their parent firms in three ways: (i) by social credit number; (ii) referring to the database of subsidiaries of listed firms provided by CSMAR; (iii) manually checking the controlling shareholders of the ETS entities in the National Enterprise Credit Information Publicity System by their social credit numbers.

Our sample contains firms listed in the country's two major stock exchanges in Shanghai and Shenzhen. Firms' financial and stock information is obtained from WIND. The sample period begins in 2009 to avoid abnormality introduced by the 2008 Global Financial Crisis and ends in 2019 to remove interruption of the COVID pandemic. The final sample of compliance firms contains 4,319 firm-ETS-year observations from 569 distinct firms in the following sectors: mining, manufacturing, electricity, gas, water supply, heating, transportation, and communications.

## 3.3 Variables

For real decisions, we consider capital expenditure as a proxy for investment and the number of employees as a proxy for employment. The explanatory variable of interest, $ETS$, indicates whether a firm is covered by the ETS. This dummy variable equals one if the firm headquarter or at least one subsidiary or branch office is covered by the ETS and zero otherwise. Intuitively, the parent firm would recognize compliance responsibility when the ETS covers its sub-entity. Moreover, we develop an abatement policy intensity measure that equals the number of subsidiaries and branch offices of a firm covered by the ETS in a year. The climate policy would have a stronger effect when a firm has more compliance entities.

[8] See, for example, Cui, Zhang, and Zheng (2018), Cao, Ho, Ma, and Teng (2021), Chen (2021), and Cui, Wang, Zhang, and Zheng (2021).

To assess firm performance after compliance coverage, we consider the following variables: revenue deflated by industrial producer price index (PPI) with 2009 as the base year; *TFP* is total factor productivity estimated using the Levinsohn and Petrin (2003) method; *TobinQ*, as a proxy for value creation, is computed as the ratio of the sum of market equity value and total liabilities to total assets; *REV per Capita*, as a proxy for efficiency, is computed as the ratio of revenue to the number of employees.

The control variables include firm size, age, leverage ratio, profitability, cash holding, asset tangibility, growth, book-to-market ratio, state ownership, previous year's stock return, and volatility. Among them, *logASSETS* is the natural logarithm of total assets as a proxy of firm size. *logAGE* is the natural logarithm of firm age. *LEVERAGE* is computed as the ratio of total liabilities to total assets. *ROA* denotes return on assets, computed as net income divided by average total assets in a fiscal year.[9] *CASH* denotes cash holding as the ratio of cash and cash equivalent to total assets. *TANGIBILITY* is the ratio of property, plant, and equipment (PPE) to total assets. *GROWTH* denotes annual revenue growth. *BM* denotes the book-to-market ratio. *SOE* is a dummy variable that equals one if the firm is a state-owned enterprise (SOE) and zero otherwise. *SKTRET* denotes the average monthly stock return in the previous year. *VOL* is the standard deviation of monthly stock returns in the previous year.

Table 4 reports the descriptive statistics.[10] Approximately 8.4% of the observations are associated with firms covered by the ETS. The average capital expenditure is 0.52 billion yuan, with a standard deviation of 1.36 billion yuan. The average number of employees is 4866, more than twice the median of 2002, suggesting that the distribution of *EMPLOYEE* is skewed toward the high end. We use the model's natural logarithm of *EMPLOYEE* to mitigate the distributional drawback. The average *TFP*, *REV per Capita*, and *TobinQ* are 11.51, 0.98 million yuan, and 2.69, respectively. *LEVERAGE* has a mean of 41.2% with a standard deviation of 21.1%. The average *ROA* and book-to-market ratio are 4.4% and

[9] Chinese firms' fiscal year coincides with the calendar years.

[10] The nominal variable values are deflated using the consumer price index (CPI) with 2009 as the benchmark year. Non-dummy variables are winsorized at the $1^{st}$ and $99^{th}$ percentiles to mitigate the influence of outliers.

42.2%, respectively. Cash and fixed assets, on average, account for 18.4% and 25.1% of total assets, respectively. The average yearly revenue growth is 14.9%. The average monthly stock return and volatility are 1.4% and 12.7%, respectively. About 36.3% of the observations are associated with SOEs.

[Insert Table 4 here.]

# 4 Empirical Results

This section presents the empirical findings. It starts with the effects of compliance coverage on investment and employment decisions, followed by the interactions between the effects and key program and institutional features, and then discusses the welfare effects.

## 4.1 Investment

Column (1) of Table 5 reports that the coefficient of $ETS$ is 0.15 and statistically significant. Economically, when a firm is covered by the ETS, its capital investment increases by 16.53% on average; that is, 86.12 million yuan. Columns (2)-(4) confirm the robustness of the finding after controlling the firm financial characteristics, stock performance, and investment in the previous year. The coefficients of $ETS$ are between 0.11 and 0.15, indicating a significant expansion in capital investment upon compliance coverage.

Among the control variables, $logASSETS$ and $ROA$ are positively correlated with $logCAPX$, suggesting that large and profitable firms invest more. The coefficients of $logAGE$ and $LEVERAGE$ are negative, indicating that mature firms and those with more debt in the capital structure are relatively less active. $CASH$ and $BM$ are also negatively correlated with investment. Intuitively, growth firms (low $BM$ ratio) invest more in capital assets, which reduces cash holding. SOEs invest less actively compared to non-SOEs. The investment decision is positively related to the previous year's capital expenditure but not the stock performance.

[Insert Table 5 here.]

To analyze what types of investment the climate program has boosted, we classify investment into the following categories: carbon-neutrality facilities ($CARBON$), natural-gas-related ($NG$), environment protection ($ENV$), retrofit ($RETRO$), and others ($UNR$). We use the project information presented in the "Constructions in Progress" section of the financial reports and classify the projects by their key words.[11] We then sum up the amount of capital invested into each category and estimate the regression model specified in Equation (1) with the natural logarithm of the amount as the dependent variable.

[Insert Table 6 here.]

Table 6 reports that $logCARBON$ is positively and significantly correlated with $ETS$, while the other investments are not. Compliance firms significantly increased investment in carbon reduction facilities compared to non-compliance firms. Although compliance has not been strictly reinforced at this initial stage, the program has raised the salience of emissions abatement and promoted firms to take investment action toward the direction of carbon reduction. Column (6) shows that research and development (R&D) expenditure is positively correlated with $ETS$, consistent with Zhu, Fan, Deng, and Xue (2019) that the climate program stimulated green innovation.

Compliance firms maintained other investments as non-compliance firms. Cao, Ho, Ma, and Teng (2021) find that firms in the electricity sector shifted some production to more carbon-efficient facilities but did not actively abandon less efficient facilities after being covered by the national ETS. Consistently, Table 11 shows that output increased after compliance coverage. The compliance firms expanded carbon abatement investment to fulfill abatement responsibilities but sustained investment in other projects to stay competitive. The phenomena can be explained by the two-stage emissions allowance allocation scheme

[11] The keywords are as follows: $CARBON$: wind power, hydropower, photovoltaic power, solar power, biomass power, nuclear power, new power resource, green power. $NG$: natural gas, gas, oil-to-gas, LNG, CNG, gas station; $ENV$: environment protection, energy saving, wastewater treatment, dirty water treatment, desulfurization, denitrification, mercury removal, defluorination, dechlorination, ash removal, dust removal, recycle, waste heat power generation, and garbage-to-energy; $RETRO$: technical retrofit, fixed asset upgrade, production line upgrade, unit retrofit, equipment modification, workshop modernization, and informatization; $UNR$ involves the other projects.

that essentially subsidizes firms with low emissions-output ratios and encourages them to produce more. On the other hand, establishing stricter and enforceable emissions targets is important to achieve further efficiency gain and greater abatement.

## 4.2 Employment

We examine how compliance responsibility affects firms' employment decisions, which is of extensive social welfare interest. Column (1) of Table 7 shows that $logEMP$ is positively correlated with $ETS$, statistically significant at the 10% level. An average firm added 372 employees after being covered by the ETS, about 6.72% of its workforce. The results remain robust after controlling firm characteristics and lagged employment.

[Insert Table 7 here.]

We conduct a heterogeneity analysis to gain insight into which types of employees increased. Employees are classified into five categories: low-skilled production workers (blue-collar labors), high-skilled workers (e.g., technicians), sale personnel, administrative staff, and R&D personnel. We measure both the level and percentage of employees and use the prefix "log" to denote the natural logarithm (of employees) and subscript "pct" for percentage (to total employees). Table 8 shows that low-skilled workers, high-skilled workers, and R&D personnel significantly increased upon compliance coverage. Economically, an average firm increased low-skilled workers by 377, high-skilled workers by 62, and R&D people by 56. The percentage of low-skilled workers increased significantly, while the percentage of administrative personnel decreased. The compliance firms not only increased hiring but also restructured the workforce.

[Insert Table 8 here.

## 4.3 Institutional Features

This section analyzes how the effects of carbon emissions compliance on firm decisions interact with key institutional characteristics, namely, state ownership, market environment, and allowance measure.

#### 4.3.1 State Ownership

SOEs are far more important in China than in Western countries. They help the government to achieve some social goals, such as creating jobs for social stability (Bai, Lu, and Tao, 2006; Liao, Liu, and Wang, 2014). As the government announced that China will become a carbon-neutral economy in 2060, SOEs should face political pressure besides the economic aspects of carbon reduction. Carbon emissions compliance is included in the evaluation and promotion of SOE executives, who are government-appointed cadres (Jotzo and Löschel, 2014; Goulder et al., 2017).

We classify firms into SOEs and non-SOEs according to their ultimate controlling parties. The results show that SOEs and non-SOEs behaved differently after compliance coverage. Panel A of Table 9 reports that non-SOEs increased capital investment without significantly expanding their workforce. Their decisions appeared to be performance-driven—the firms increased investment to prepare for compliance and tried to stay competitive by controlling labor costs.[12] In contrast, SOEs significantly expanded employment but did not increase investment. In China, strategic products and service prices are not market-determined but administered. SOEs in these sectors have a weak incentive to abate carbon emissions as they cannot pass costs to consumers. In the past, SOEs were directed to execute policies addressing various environmental issues (Karplus and Zhang, 2017; Hsu, Liang, and Matos, 2021). Old habits cultivated by the top-down administrative order approach lead to a "wait-and-see" attitude. SOEs' political connection could make non-compliance penalties more difficult. The phenomenon can also be related to SOEs' market dominance, which allows them to shift the abatement burden to other firms along the supply chain. On the hiring side, Chinese governments promote "green employment," and SOEs are regarded as a primary source of job creation.

The significant presence of SOEs in the Chinese economy posts challenges to the carbon

[12] Interviews with private firms indicate many plans to reduce emissions through material recycling, technology innovation, and equipment retrofit.

trading program. According to Munnings et al. (2016), regulators could consider imposing carbon taxes on SOEs while regulating private firms through the ETS if state ownership significantly hinders the implementation of the ETS. For the ETS to harness market forces to achieve emissions goals cost-efficiently, the government has an important role in providing oversight to the market to protect integrity and equity. However, a politically-driven agenda and excessive government interference could overshadow the market-oriented program. The findings advocate institutional and industrial reforms in a broader context to remove barriers to the healthy development of the ETS.

[Insert Table 9 here.]

#### 4.3.2 Market Liberalness

A key consideration for China to adopt the emissions trading program (versus carbon taxation) is to let the market forces play a decisive role in achieving abatement more cost-efficiently (Goulder et al., 2017; Karplus and Zhang, 2017). China's regional discrepancy provides a natural setting to study the interactions between market liberalness and the ETS effects. We proxy market liberalness with the provincial marketization index developed in Wang, Hu, and Fan (2021) and widely used in the literature (See, for example, Jiang, Lee, and Yue, 2010; Li, Wang, Cheung, and Jiang, 2011). The measure considers the following market components: production factors, development of non-state sectors, development of market intermediaries, legal environment, and government-market relationship. Intuitively, if a region has a higher marketization index, it has a more liberal market, and firms there have more freedom and are less subject to politically driven agendas.

We construct a dummy variable, $MI$, that equals zero if the marketization index of the province/city where a firm's headquarter locates ranks in the top five in a year and one otherwise. We choose the top five as the threshold to allocate the regional pilots into two groups in close number—it tags four regional ETSs as "more liberal market" and the other three as "less liberal market." Panel B of Table 9 reports that the compliance firms located in the regions with more liberal markets significantly grew investment; those in the regions with less liberal markets only expanded employment. The patterns echo those of SOEs and non-SOEs, suggesting that non-market factors could substantially undermine the effectiveness of the market-based ETS.

### 4.3.3 Compliance Allowance Measures

Some regional pilots apply mass-based (emissions quantity) allowance measures, and some use intensity-based measures. The two-stage allowance allocation scheme largely blurs the difference between the two measures, as the final allowance is determined by end-of-period production, benchmarked to the sector emissions-output ratio. Nonetheless, subtle differences exist. Policymakers hint that China's ETS may switch to the cap-and-trade approach when it is more mature. The mess-based measure is perceived as more stringent, as emissions limits are expected to repress production when binding. In contrast, the intensity-based measure is viewed as relatively lenient without setting an explicit emissions limit.

We use a dummy variable to identify firms explicitly subject to the intensity-based measure. They include electricity and heating firms in all the pilots, aviation firms in Shanghai, and cement and steel firms in Guangdong province. We estimate the following regression model:

$$\begin{aligned} Decision_{i,t} =& \theta_1 ETS_{i,t} \times RATEBASE_{i,j} + \theta_2 ETS_{i,t} + \theta_3 RATEBASE_{i,j} + \\ & \gamma Controls_{i,t} + \epsilon_{i,t}, \end{aligned} \tag{3}$$

where $RATEBASE_{i,j}$ denotes the dummy variable that equals one if firm $i$ in sector $j$ is subject to the intensity-based measure and zero otherwise.

Columns (1) and (2) in Table 10 show that the interaction terms of *ETS* and *RATEBASE* are positively and significantly correlated with $logCAPX$. The coefficients are two times larger than the coefficients of $ETS$, suggesting that the intensity-based measure influenced firms' investment decisions more. Why were the more stringent mass-based measures less effective? A possible explanation is that at the initial stage, a more stringent policy could face a stronger headwind in promoting firms to take action. Calel and Dechezleprêtre (2016) and Shapiro and Walker (2018) show that strict mass-based policies result in adverse production shocks and a shift of production to non-compliance entities/facilities (carbon leakage). In contrast, China's ETS, which sacrifices cost-effectiveness for flexibility, appears to help reduce resistance and inertia. Effectively subsidizing firms with higher carbon efficiency encouraged investment in abatement facilities. The policy also allows firms to adapt output to economic growth, mitigating their fear of economic and policy uncertainties.

[Insert Table 10 here.]

## 4.4 Economic Welfare

Economic welfare constitutes the ultimate goal of carbon abatement policies. When the ETS affects firms' investment and employment decisions and climate behaviors, what are the implications for economic welfare at the micro level? This section addresses the question from firm performance and worker wage perspectives.

### 4.4.1 Firm Performance

We consider (1) output proxied by revenue deflated by producer price index (PPI); (2) productivity proxied by total factor productivity ($TFP$); (3) efficiency proxied by revenue per capita (*REV per Capita*); and (4) firm value creation proxied by Tobin's Q. We estimate the regression model in Equation (1) with the above measures as dependent variables.

Columns (1)-(2) of Table 11 show that $logOUTPUT$ is positively and significantly correlated with $ETS$, implying that output increased upon compliance coverage. The finding supports the goal of the compliance quota allocation scheme to encourage production from more carbon-efficient entities. However, carbon dioxide emissions levels could increase or decrease at the current stage. It is important to gather accurate emissions and compliance data to assess the abatement performance of the ETS.

Columns (3)-(8) report that $TFP$, *REV per Capita*, and $TobinQ$ are not significantly correlated with $ETS$, suggesting that firms were able to maintain their productivity and operating efficiency. However, SOE's operating efficiency, measured by revenue per capita, decreased after the ETS coverage, consistent with the evidence that compliance SOEs increased hiring but not output and investment. The program balanced promoting firms to take climate action and avoiding adverse productivity shocks. We emphasize that China's ETS still faces non-trivial challenges in future implementation. The challenges include emissions measuring, reporting and verification, compliance supervision, determining carbon prices, and ensuring fair and liquid carbon trading. China's industry complexity, institution heterogeneity, and regional disparity add weight to those challenges.

[Insert Table 11 here.]

#### 4.4.2 Real Wages

The wage has vast economic interest and social welfare implications. We construct the following dependent variables for real wage: (1) $WAGE$ is the aggregate wage of all employees; (2) $AWAGE$ is the average wage; (3) $EWAGE$ is the average wage of employees excluding executives and directors; and (4) $MWAGE$ is the average wage of executives and directors. We use these variables as dependent variables in Equation (1).

[Insert Table 12 here.]

Columns (1) and (3) of Table 12 show that the total and average wages are not significantly correlated with $ETS$, indicating overall wages did not change substantially upon compliance coverage. However, the average non-executive wage is negatively and significantly correlated with $ETS$, suggesting that ordinary workers' wages in compliance firms are reduced relative to non-compliance firms. In contrast, there are no significant differences in executive salary. The finding echos Liu, Tan, and Zhang (2021) that China's pollution control policy significantly reduced labor demand and that low-skilled employees were more affected. As firms adapted to carbon reduction and simultaneously struggled to stay competitive, the expense came from ordinary workers. Columns (4), (6), and (8) indicate that the phenomenon is more prominent in SOEs, in line with the pattern that compliance SOEs increased hiring. The pattern seems to be SOEs expanded "green employment" and controlled labor costs trimming real wages.

# 5 Robustness Checks

This section conducts a battery of robustness tests. One may concern that the compliance shocks did not apply randomly to firms, though truly randomized control is extremely rare in environmental policy research due to the intentional selection of policymakers (Aldy, Auffhammer, Cropper, Fraas, and Morgenstern, 2022). Following the literature, we apply propensity score matching (PSM) in DiD for robustness check.[13]

The nearest neighbor matching estimator measures the similarity between the ETS and non-compliance firms. Each year, paired firms share the same two-digit industrial classification code and have the shortest Mahalanobis distance computed based on pre-treatment covariates that affected both emitting behaviors and decisions. We follow Bolton and Kacperczyk (2021) to consider the following covariates: firm age, total assets, leverage, return on assets, book-to-market ratio, tangibility, and revenue growth. There is no explicit rule on how many pre-treatment year(s) to be used for the matching, so we did it in two ways: (1) using the sample from 2009 to 2012, the entire pre-treatment period, as in Heyman, Sjöholm, and Tingvall (2007) and Cui et al. (2021); (2) using the sample of 2012, the year before the earliest treatment, in the same spirit of Cao et al. (2021) and Cicala (2015). The first involves extensive data to reinforce robustness, and the second uses new information. We follow Zhu, Fan, Deng, and Xue (2019) to include firms never covered by the ETS in the control group and apply one-to-one matching without replacement. The untabulated results show no significant differences between the covariates of the matched firms in the pre-treatment periods, indicating that the treatment and control groups were comparable before the ETS shock.

Columns (1) and (2) of Table 13 show that for the PSM DiD sample, $logCAPX$ is positively and significantly correlated with $ETS$ for the pre-treatment samples constructed in both ways; Columns (6) and (7) report that *logEMP* are positively and significantly correlated with $ETS$. The results confirm the main findings— firms increased investment and expanded

[13]See, for example, Fowlie, Holland, and Mansur (2012), Ferris, Shadbegian, and Wolverton (2014), Calel and Dechezleprêtre (2016), Liu, Tan, and Zhang (2021). We do not select PSM DiD as the primary empirical methodology because it significantly reduces the sample size.

employment after being covered by the carbon abatement program.

[Insert Table 13 here.]

Our baseline analysis focuses on sectors of intensive carbon emissions. To mitigate the concern that the practice could bias toward more favorable findings by leaving out other industries, we conduct regressions using the full sample involving all sectors except financial services. Columns (3) and (8) of Table 13 report that both *logCAPX* and *logEMP* are positively and significantly correlated with $ETS$, implying that our findings are not entirely driven by high carbon-emitting sectors only.

Our treatment sample includes firms covered by the national ETS. The reason is as follows: the national ETS announced its implementation provisions in 2017, four years before its opening. Firms knew the coverage and formed compliance expectations that could affect their climate decisions and actions. We estimate the regression model excluding the firms only covered by the national ETS from the treatment sample. It shows that the full sample includes 569 distinct firms, 140 (24.6%) of which are only covered by the national ETS. Columns (4) and (9) of Table 13 show that *logCAPX* and *logEMP* are positively and significantly correlated with $ETS$. Our findings are robust with and without the national ETS firms.

We examine how compliance intensity affects firm decisions. To proxy policy intensity, we construct *ETS_Intensity* as the number of times a firm's headquarter, subsidiaries, and branch offices are covered by the ETS in a year. The hypothesis is that a firm is more active if it faces more intense compliance requirements. We estimate the regression model in Equation (1) with *ETS_Intensity* as the explanatory variable of interest. Columns (5) and (10) of Table 13 show that *logCAPX* and *logEMP* are positively and significantly correlated with $ETS\_Intensity$, adding robustness to our findings that firms facing more intense policies took more active actions.

Recent econometric studies find that DiD estimates may be biased due to heterogeneity in treatment effect embedded in staggered timing of treatment (See, for example, de Chaisemartin and D'Haultfœuille, 2020; Goodman-Bacon, 2021; Baker, Larcker, and Wang, 2022). To address the issue, we alternatively apply a modified DiD estimator proposed by Callaway and Sant'Anna (2021) that allows for dynamic selection of control groups and covariates (Baker, Larcker, and Wang, 2022).[14] The untabulated results show that the pre-treatment estimates of $logCAPEX$ and $logEMP$ are statistically indifferent. Still, the post-treatment estimates increased monotonically, implying that the real decisions significantly responded to compliance coverage.

# 6 Conclusion

China's ETS adopts a salient two-stage allowance allocation scheme in the initial stage, which significantly differs from the cap-and-trade systems in developed economies. The program needs to be understood in the following context: (1) China chose this emissions trading program over carbon taxation to give companies greater autonomy in determining how to achieve the emissions targets; (2) the design of the program considered the country's socioeconomic complexities, possible impacts on the economy, and continuously evolving policy environment; (3) as for the past policies, China adopted a learning-by-doing approach. This paper examines the program's effects on real decisions and assesses to what extent the ETS has achieved the goal of evoking climate awareness and changing emitting behaviors.

We find that firms significantly increased carbon abatement investment and expanded their production workforce after being covered by the emissions trading program. The program successfully promoted firms to take action without causing adverse productivity and efficiency shocks. On the other hand, firms' climate decisions are influenced by state ownership and regional heterogeneity. State-owned enterprises (SOEs) and firms in regions with less liberal markets hired more employees but did not expand investment. In contrast, non-SOEs and firms in more liberal markets grew investment only, alarming that economic distortions, such as SOE privileges and excessive government influence, could overshadow this market-oriented program.

[14]The main idea of Callaway and Sant'Anna (2021) estimator is to estimate the group-time treatment effects at staggered times separately and aggregate the effects by different weights computed by the length of exposure to the treatment time and group size. See their insightful paper for more details.

# References


Aldy, Joseph E., Maximilian Auffhammer, Maureen Cropper, Arthur Fraas, and Richard Morgenstern, 2022, Looking Back at 50 Years of the Clean Air Act, *Journal of Economic Literature* 60, 179–232.

Bai, Chong-En, Jiangyong Lu, and Zhigang Tao, 2006, The Multitask Theory of State Enterprise Reform: Empirical Evidence from China, *American Economic Review* 96, 353–357.

Baker, Andrew C, David F Larcker, and Charles C.Y. Wang, 2022, How much Should We Trust Staggered Difference-in-Differences Estimates?, *Journal of Financial Economics* 144, 370–395.

Bayer, Patrick, and Michaël Aklin, 2020, The European Union Emissions Trading System reduced CO2 emissions despite low prices, *Proceedings of the National Academy of Sciences of the United States of America* 117, 8804–8812.

Bolton, Patrick, and Marcin Kacperczyk, 2021, Do Investors Care About Carbon Risk?, *Journal of Financial Economics* 142, 517–549.

Calel, Raphael, and Antoine Dechezleprêtre, 2016, Environmental policy and directed technological change: evidence from the european carbon market, *Review of economics and statistics* 98, 173–191.

Calel, Raphael, and Antoine Dechezleprêtre, 2016, Environmental Policy and Directed Technological Change: Evidence from the European Carbon Market, *Review of Economics and Statistics* 98, 173–191.

Callaway, Brantly, and Pedro H.C. Sant'Anna, 2021, Difference-in-Differences with Multiple Time Periods, *Journal of Econometrics* 225, 200–230.

Cao, Jing, Mun S. Ho, Rong Ma, and Fei Teng, 2021, When Carbon Emission Trading Meets a Regulated Industry: Evidence from the Electricity Sector of China, *Journal of Public Economics* 200, 104470.

Chen, Ruoyu, 2021, Evaluating Power Sector Emissions under China's Regional Carbon ETS Pilots: A View from Space, *SSRN Electronic Journal* .

Cicala, Steve, 2015, When Does Regulation Distort Costs? Lessons from Fuel Procurement in US Electricity Generation, *American Economic Review* 105, 411–444.

Cui, Jingbo, Chunhua Wang, Junjie Zhang, and Yang Zheng, 2021, The Effectiveness of China's Regional Carbon Market Pilots in Reducing Firm Emissions, *Proceedings of the National Academy of Sciences* 118.

Cui, Jingbo, Junjie Zhang, and Yang Zheng, 2018, Carbon Pricing Induces Innovation: Evidence from China's Regional Carbon Market Pilots, *AEA Papers and Proceedings* 108, 453–457.

de Chaisemartin, Clément, and Xavier D'Haultfœuille, 2020, Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects, *American Economic Review* 110, 2964–2996.

de Chaisemartin, Clément, and Xavier D'Haultfoeuille, 2022, Two-Way Fixed Effects and Differences-in-Differences with Heterogeneous Treatment Effects: A Survey, *Working paper* .

Duan, Maosheng, and Li Zhou, 2017, Key issues in designing china's national carbon emissions trading system, *Economics of Energy and Environmental Policy* 6, 55–72.

Ferris, Ann E., Ronald J. Shadbegian, and Ann Wolverton, 2014, The Effect of Environmental Regulation on Power Sector Employment: Phase I of the Title IV SO2 Trading Program , *Journal of the Association of Environmental and Resource Economists* 1, 521–553.

Fowlie, Meredith, Stephen P Holland, and Erin T Mansur, 2012, What Do Emissions Markets Deliver and to Whom? Evidence from Southern California's NOx Trading Program, *American Economic Review* 102, 965–993.

Gallagher, Kelly Sims, Fang Zhang, Robbie Orvis, Jeffrey Rissman, and Qiang Liu, 2019, Assessing the Policy Gaps for Achieving China's Climate Targets in the Paris Agreement, *Nature Communications* 10, 1256.

Goodman-Bacon, Andrew, 2021, Difference-in-Differences with Variation in Treatment Timing, *Journal of Econometrics* 225, 254–277.

Goulder, Lawrence, Richard Morgenstern, Clayton Munnings, and Jeremy Schreifels, 2017, China's national carbon dioxide emission trading system: An introduction, *Economics of Energy and Environmental Policy* 6, 1–18.

Goulder, Lawrence H, Xianling Long, Jieyi Lu, and Richard D Morgenstern, 2022, China's Unconventional Nationwide CO2 Emissions Trading System: Cost-Effectiveness and Distributional Impacts, *Journal of Environmental Economics and Management* 111, 102561.

Goulder, Lawrence H., and Richard D. Morgenstern, 2018, China's Rate-Based Approach to Reducing CO 2 Emissions: Attractions, Limitations, and Alternatives , *AEA Papers and Proceedings* 108, 458–462.

Heyman, Fredrik, Fredrik Sjöholm, and Patrik Gustavsson Tingvall, 2007, Is There Really a Foreign Ownership Wage Premium? Evidence from Matched Employer–Employee Data, *Journal of International Economics* 73, 355–376.

Hsu, Po-Hsuan, Hao Liang, and Pedro Matos, 2021, Leviathan Inc. and Corporate Environmental Engagement, *Management Science* 94–108.

Jiang, Guohua, Charles M.C. Lee, and Heng Yue, 2010, Tunneling Through Intercorporate Loans: The China Experience, *Journal of Financial Economics* 98, 1–20.

Jotzo, Frank, and Andreas Löschel, 2014, Emissions trading in china: Emerging experiences and international lessons, *Energy Policy* 75, 3–8.

Karplus, Valerie, and Xiliang Zhang, 2017, Incentivizing Firm Compliance with China's National Emissions Trading System, *Economics of Energy and Environmental Policy* 6, 73–86.

Levinsohn, James, and Amil Petrin, 2003, Estimating Production Functions Using Inputs to Control for Unobservables, *Review of Economic Studies* 70, 317–341.

Li, Kai, Tan Wang, Yan-Leung Cheung, and Ping Jiang, 2011, Privatization and Risk Sharing: Evidence from the Split Share Structure Reform in China, *Review of Financial Studies* 24, 2499–2525.

Liao, Li, Bibo Liu, and Hao Wang, 2014, China's Secondary Privatization: Perspectives from the Split-Share Structure Reform, *Journal of Financial Economics* 113, 500–518.

Liu, Mengdi, Ruipeng Tan, and Bing Zhang, 2021, The Costs of "Blue Sky": Environmental Regulation, Technology Upgrading, and Labor Demand in China, *Journal of Development Economics* 150, 102610.

Munnings, Clayton, Richard Morgenstern, Zhongmin Wang, and Xu Liu, 2016, Assessing the design of three carbon trading pilot programs in china, *Energy Policy* 96, 688–699.

Pang, Tao, and Maosheng Duan, 2016, Cap setting and allowance allocation in china's emissions trading pilot programmes: special issues and innovative solutions, *Climate Policy* 16, 815–835.

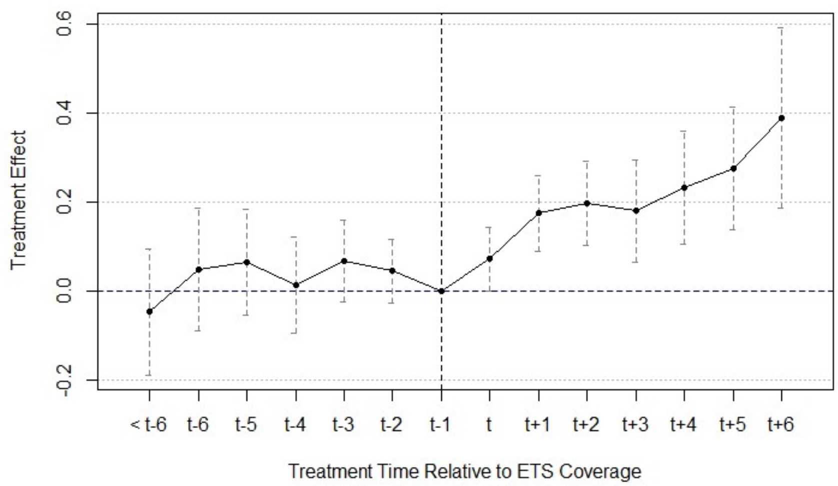
Pizer, William A., and Xiliang Zhang, 2018, China's New National Carbon Market, *AEA Papers and Proceedings* 108, 463–467.

Shapiro, Joseph S, and Reed Walker, 2018, Why is pollution from us manufacturing declining? the roles of environmental regulation, productivity, and trade, *American Economic Review* 108, 3814–54.

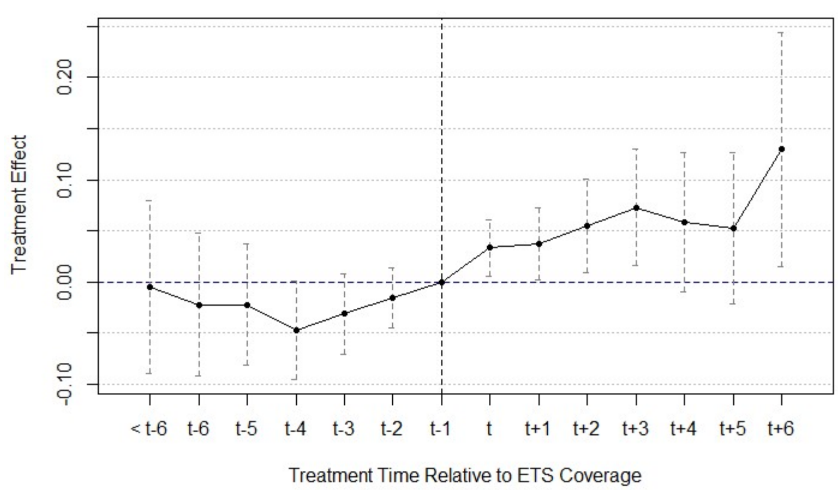
Wang, Xiaopeng, Lipeng Hu, and Gang Fan, 2021, *Marketization Index of China's Provinces: NERI Report 2021* (Social Science Academic Press China, Beijing).

Zhu, Junming, Yichun Fan, Xinghua Deng, and Lan Xue, 2019, Low-Carbon Innovation Induced by Emissions Trading in China, *Nature Communications* 10, 4088.

Figure 1: Pre-Trend Tests for DiD estimation of $logCAPX$ and $logEMP$
This figure plots the evolution of coefficients of $ETS$ estimated using an event-study regression model based on Equation (2). Panels (a) and (b) are for investment ( $logCAPX$) and employment ($logEMP$) decisions, respectively. The horizontal axis represents treatment time relative to compliance coverage; the vertical axis showcases the treatment effect. The vertical dotted lines with endpoints represent the 90% confidential interval of coefficient estimates.




(a) Investment




(b) Employment

Table 1: China's Major Climate Policies

| Time | Documents | Authorities | Brief Description |
|---|---|---|---|
| September 2010 | Decision on Accelerating the Cultivation and Development of Strategic Emerging Industries | State Council | Proposing to establish ETS for the first time. |
| March 2011 | 12th Five-Year Plan | National People's Congress | Declaring establishing ETS market by steps. |
| October 2011 | Notice on Carrying out the Pilot Work of Carbon Emissions Trading | National Development and Reform Commission | Approving to establish seven ETS pilots in Beijing, Shanghai, Tianjin, Chongqing Guangdong, Hubei, and Shenzhen. |
| November 2012 | Report of the 18th National Congress of the Communist Party of China | Central Committee of the Communist Party of China | Establishing carbon ETS pilots. |
| January 2013 - June 2014 | Implementation of regional ETS Pilots | Provincial Governments | Seven ETS pilots were implemented serially. |
| January 2016 | Notice on Effectively Launching the National Carbon Emissions Trading Market | National Development and Reform Commission | Declaring eight industries covered by the national ETS. |
| December 2017 | Work Plan for National Carbon ETS Market (Power Sector) | National Development and Reform Commission | Marking the official start of establishing the national carbon market |
| December 2020 | 2019-2020 Implementation Plan for the Full-Scale Setting and Distribution of National Carbon Emissions Trading Allowances | Ministry of Ecology and Environment | Clarifying the coverage and allocation methods of carbon emission allowance quotas for national ETS. |
| December 2020 | Measures for the Administration of Carbon Emissions Trading | Ministry of Ecology and Environment | Establishing guidelines for participating and trading in the national ETS. |

Table 2: Information of China's ETS

This table presents information on China's regional and national ETSs. Coverage is the percentage of carbon emission produced by compliance entities to the regions or country's total carbon emissions. Cap is the aggregate emissions captivity of a regional or national market.

| Market | Coverage | Cap ($MtCO_2$) | Trading Volume ($MtCO_2$) Year 2021 | Vol/Cap | Average Price (USD) Year 2021 |
|---|---|---|---|---|---|
| Beijing | 24% | 35 | 1.86 | 5.30% | 9.48 |
| Chongqing | 51% | 78.39 | 1.13 | 1.45% | 4.11 |
| Guangdong | 40% | 265 | 27.00 | 10.19% | 5.91 |
| Hubei | 27% | 166 | 3.51 | 2.12% | 5.32 |
| Shanghai | 57% | 105 | 0.39 | 0.37% | 6.23 |
| Shenzhen | 40% | 31.5 | 2.99 | 9.51% | 1.74 |
| Tianjin | 55% | 120 | 5.85 | 4.87% | 4.73 |
| National Market | 44% | 4500 | 177.99 | 3.96% | 7.23 |

Table 3: Variable Definitions

| Variables | Definition |
|---|---|
| $CAPX$ | The amount of capital expenditure. |
| $EMPLOYEE$ | The number of employees. |
| $CARBON$ | The amount of capital expenditure for the zero-carbon facilities. |
| $NG$ | The amount of capital expenditure for the natural-gas-related projects. |
| $ENV$ | The amount of capital expenditure for the environment protection projects. |
| $RETRO$ | The amount of capital expenditure for the retrofit projects. |
| $UNR$ | The amount of capital expenditure for other projects except for the above four categories. |
| $RDSPEND$ | The amount of R&D expenditure. |
| $LOWSKILL$ | The number of low-skilled production workers. |
| $LOWSKILL\_pct$ | The percentage of low-skilled workers to total employees. |
| $HIGHSKILL$ | The number of high-skilled workers. |
| $HIGHKILL\_pct$ | The percentage of high-skilled workers to total employees. |
| $SALEMAN$ | The number of sale people. |
| $SALEMAN\_pct$ | The percentage of sale people to total employees. |
| $ADM$ | The number of administrative staff. |
| $ADM\_pct$ | The percentage of the number of administrative staff to total employees. |
| $RDPerson$ | The number of R&D staff. |
| $RDPerson\_pct$ | The percentage of R&D staff to total employees. |
| $ETS$ | A dummy variable that equals one if the firm is covered by an ETS and zero otherwise. |
| $ETS\_Intensity$ | The number of times different ETS pilots cover the same listed firm in a year. |
| $ASSETS$ | The amount of total assets. |
| $AGE$ | Firm age in year. |
| $LEVERAGE$ | The ratio of total liabilities to total assets. |
| $ROA$ | Return on assets computed as the net income divided by the average total assets. |
| $CASH$ | Cash and equivalent divided by total assets. |
| $TANGIBILITY$ | Property, plant, and equipment (PPE) divided by total assets. |
| $GROWTH$ | Annual revenue growth rate. |
| $SOE$ | A dummy variable that equals one if the firm is a state-owned enterprise and zero otherwise. |
| $BM$ | The book-to-market ratio. Book equity equals total shareholder equity minus the book value of preferred stocks. |
| $SKTRET$ | The average monthly stock return in a fiscal year. |
| $VOL$ | The standard deviation of monthly stock return in a fiscal year. |
| $OUTPUT$ | The amount of revenue deflated by industrial PPI with 2009 as the base year. |
| $TFP$ | The total factor productivity computed following Levinsohn and Petrin (2003). |
| $REVperCapita$ | The ratio of revenue to the number of employees. |
| $TobinQ$ | The ratio of market equity and total liabilities to total assets. |
| $WAGES$ | The total wage paid to all employees. |
| $AWAGES$ | The average wage paid to all employees. |
| $EWAGES$ | The average wage paid to all employees, excluding executives and directors. |
| $MWAGES$ | The average wage paid to executives and directors. |

Table 4: Descriptive Statistics

This table presents the summary statistics of the key variables. See Table 3 for variable definitions. Nominal values are adjusted with the consumer price index (CPI), with 2009 as the base year. The variables are winsorized at the $1^{st}$ and $99^{th}$ percentiles, respectively.

| | Obs. | Mean | Std | Min | Median | Max |
|---|---|---|---|---|---|---|
| Dependent Variables | | | | | | |
| *CAPX* (RMB in billions) | 21173 | 0.521 | 1.368 | 0.001 | 0.127 | 10.257 |
| *EMPLOYEE* | 21218 | 4866 | 8981 | 113 | 2002 | 61938 |
| *OUTPUT* (RMB in billions) | 20338 | 0.055 | 0.128 | 0.001 | 0.015 | 0.874 |
| *TFP* | 18628 | 12.932 | 0.648 | 11.438 | 12.884 | 14.696 |
| *REVperCapita* (RMB in millions) | 21218 | 0.983 | 1.021 | 0.122 | 0.663 | 6.842 |
| *TobinQ* | 21122 | 2.687 | 1.948 | 0.841 | 2.067 | 11.979 |
| *WAGES* (RMB in billions) | 21189 | 0.425 | 0.904 | 0.009 | 0.142 | 6.388 |
| *AWAGES* (RMB in thousands) | 21189 | 84.702 | 47.168 | 22.907 | 73.322 | 302.733 |
| *EWAGES* (RMB in thousands) | 21189 | 83.709 | 48.194 | 21.894 | 71.896 | 317.180 |
| *MWAGES* (RMB in thousands) | 21189 | 275.296 | 200.133 | 41.272 | 221.976 | 1215.913 |
| Independent Variables | | | | | | |
| *ETS* | 21218 | 0.084 | 0.278 | 0 | 0 | 1 |
| *ASSETS*(RMB in billions) | 21218 | 9.725 | 22.858 | 0.304 | 2.912 | 166.449 |
| *AGE* (year) | 21218 | 18.006 | 5.660 | 1 | 18 | 65 |
| *LEVERAGE* | 21218 | 0.412 | 0.211 | 0.048 | 0.400 | 0.983 |
| *ROA* | 21218 | 0.044 | 0.067 | -0.243 | 0.042 | 0.232 |
| *CASH* | 21218 | 0.184 | 0.138 | 0.012 | 0.144 | 0.682 |
| *TANGIBILITY* | 21218 | 0.251 | 0.160 | 0.012 | 0.218 | 0.733 |
| *GROWTH* | 21218 | 0.149 | 0.412 | -0.543 | 0.083 | 2.746 |
| *SOE* | 21218 | 0.363 | 0.481 | 0 | 0 | 1 |
| *BM* | 21122 | 0.422 | 0.296 | 0.007 | 0.349 | 1.565 |
| *SKTRET* | 19382 | 0.014 | 0.044 | -0.068 | 0.008 | 0.151 |
| *VOL* | 19382 | 0.127 | 0.056 | 0.044 | 0.115 | 0.351 |

Table 5: Capital Investment and ETS

This table presents the regression results of capital investment on ETS. See Table 3 for the definitions of the variables. Standard errors, reported in parentheses, are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

| | $logCAPX_{i,t}$ | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $ETS_{i,t}$ | 0.153** | 0.119*** | 0.128*** | 0.105*** |
| | (0.060) | (0.043) | (0.044) | (0.034) |
| $logASSETS_{i,t}$ | | 1.222*** | 1.232*** | 0.842*** |
| | | (0.034) | (0.037) | (0.033) |
| $logAGE_{i,t}$ | | -1.024*** | -1.205*** | -0.773*** |
| | | (0.224) | (0.268) | (0.208) |
| $LEVERAGE_{i,t}$ | | -0.360*** | -0.401*** | -0.349*** |
| | | (0.113) | (0.119) | (0.100) |
| $ROA_{i,t}$ | | 1.153*** | 1.242*** | 1.289*** |
| | | (0.175) | (0.183) | (0.163) |
| $CASH_{i,t}$ | | -0.923*** | -0.616*** | -0.372*** |
| | | (0.100) | (0.117) | (0.099) |
| $TANGIBILITY_{i,t}$ | | -0.276* | -0.323** | -0.887*** |
| | | (0.152) | (0.158) | (0.131) |
| $GROWTH_{i,t}$ | | -0.006 | -0.003 | 0.140*** |
| | | (0.020) | (0.021) | (0.023) |
| $SOE_{i,t}$ | | -0.218** | -0.230** | -0.170** |
| | | (0.091) | (0.091) | (0.074) |
| $BM_{i,t}$ | | | -0.190*** | -0.143*** |
| | | | (0.063) | (0.053) |
| $SKTRET_{i,t}$ | | | -0.858*** | -0.383 |
| | | | (0.274) | (0.261) |
| $VOL_{i,t}$ | | | -0.131 | -0.052 |
| | | | (0.185) | (0.172) |
| $logCAPX_{i,t-1}$ | | | | 0.339*** |
| | | | | (0.011) |
| Firm FE | ✓ | ✓ | ✓ | ✓ |
| Year-Province FE | ✓ | ✓ | ✓ | ✓ |
| Year-Industry FE | ✓ | ✓ | ✓ | ✓ |
| Observations | 21,172 | 21,172 | 19,322 | 19,322 |
| Adjusted $R^2$ | 0.730 | 0.807 | 0.814 | 0.836 |

Table 6: Investment in Different Projects

This table presents the regression results of different project investments on the ETS. $logCARBON$, $logNG$, $logENV$, $logRETRO$, and $logUNR$ are the logarithm of capital expenditure for the zero-carbon facilities, natural gas related projects, environmental protection projects, retrofit projects, and other projects, respectively. $logRDSPEND$ is the logarithm of R&D expenditure. See Table 3 for the definitions of the explanatory variables. Standard errors, reported in parentheses, are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

| | $logCARBON_{i,t}$ | $logNG_{i,t}$ | $logENV_{i,t}$ | $logRETRO_{i,t}$ | $logUNR_{i,t}$ | $logRDSPEND_{i,t}$ |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $ETS_{i,t}$ | 0.827** | -0.117 | -0.331 | -0.152 | 0.188 | 0.096** |
| | (0.325) | (0.144) | (0.302) | (0.386) | (0.148) | (0.041) |
| $logASSETS_{i,t}$ | 1.126*** | 0.125 | 0.465*** | 0.668*** | 1.725*** | 0.795*** |
| | (0.173) | (0.087) | (0.180) | (0.229) | (0.109) | (0.031) |
| $logAGE_{i,t}$ | -0.564 | -0.779 | 2.209 | -0.051 | 0.028 | -0.528** |
| | (1.577) | (0.733) | (1.583) | (2.186) | (0.939) | (0.241) |
| $LEVERAGE_{i,t}$ | 0.455 | 0.129 | -1.539** | -0.815 | -0.903** | -0.239** |
| | (0.554) | (0.255) | (0.640) | (0.728) | (0.372) | (0.100) |
| $ROA_{i,t}$ | -0.003 | 0.003 | -0.009 | 0.018 | 0.017** | 0.572*** |
| | (0.009) | (0.005) | (0.010) | (0.012) | (0.007) | (0.156) |
| $CASH_{i,t}$ | -0.481 | 0.154 | -0.157 | 1.591** | -1.272*** | -0.129 |
| | (0.507) | (0.296) | (0.561) | (0.762) | (0.416) | (0.083) |
| $TANGIBILITY_{i,t}$ | 1.807*** | 0.363 | 0.665 | 2.390*** | -0.977** | 0.437*** |
| | (0.630) | (0.398) | (0.720) | (0.909) | (0.485) | (0.142) |
| $GROWTH_{i,t}$ | -0.074 | 0.005 | -0.000 | -0.274** | -0.062 | 0.007 |
| | (0.105) | (0.056) | (0.112) | (0.135) | (0.081) | (0.021) |
| $SOE_{i,t}$ | 0.541 | 0.059 | 0.756 | 0.985 | -0.616** | -0.049 |
| | (0.392) | (0.243) | (0.500) | (0.642) | (0.313) | (0.079) |
| $BM_{i,t}$ | -0.106 | 0.331* | 0.982** | 0.302 | -0.197 | -0.133** |
| | (0.401) | (0.191) | (0.393) | (0.470) | (0.184) | (0.055) |
| $SKTRET_{i,t}$ | -0.511 | -0.402 | 1.000 | -1.278 | -0.933 | -0.792*** |
| | (1.380) | (0.769) | (1.525) | (2.011) | (1.104) | (0.201) |
| $VOL_{i,t}$ | 0.857 | 0.074 | -0.008 | 0.163 | -0.271 | -0.035 |
| | (0.869) | (0.507) | (1.016) | (1.283) | (0.695) | (0.124) |
| Firm FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Year-Province FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Year-Industry FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Observations | 17,978 | 17,978 | 17,978 | 17,978 | 17,978 | 15,825 |
| Adjusted $R^2$ | 0.529 | 0.526 | 0.506 | 0.488 | 0.444 | 0.871 |

Table 7: Employment and ETS

This table presents the regression results of employment on the ETS. $logEMP$ is the logarithm of the number of employees. See Table 3 for the definitions of the explanatory variables. Standard errors, reported in parentheses, are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

| | $logEMP_{i,t}$ | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $ETS_{i,t}$ | 0.065* | 0.060** | 0.066*** | 0.029** |
| | (0.037) | (0.025) | (0.025) | (0.014) |
| $logASSETS_{i,t}$ | | 0.671*** | 0.660*** | 0.348*** |
| | | (0.018) | (0.019) | (0.016) |
| $logAGE_{i,t}$ | | 0.350*** | 0.421*** | 0.114 |
| | | (0.134) | (0.154) | (0.085) |
| $LEVERAGE_{i,t}$ | | 0.119** | 0.117* | 0.039 |
| | | (0.058) | (0.061) | (0.039) |
| $ROA_{i,t}$ | | -0.087 | -0.134 | 0.030 |
| | | (0.085) | (0.090) | (0.070) |
| $CASH_{i,t}$ | | -0.353*** | -0.320*** | -0.167*** |
| | | (0.048) | (0.053) | (0.037) |
| $TANGIBILITY_{i,t}$ | | 0.583*** | 0.558*** | 0.264*** |
| | | (0.075) | (0.077) | (0.053) |
| $GROWTH_{i,t}$ | | 0.015 | 0.020* | 0.170*** |
| | | (0.011) | (0.011) | (0.012) |
| $SOE_{i,t}$ | | 0.108** | 0.109** | 0.039 |
| | | (0.046) | (0.046) | (0.027) |
| $BM_{i,t}$ | | | 0.004 | 0.026 |
| | | | (0.033) | (0.024) |
| $SKTRET_{i,t}$ | | | 0.224* | 0.101 |
| | | | (0.121) | (0.099) |
| $VOL_{i,t}$ | | | -0.174** | -0.030 |
| | | | (0.076) | (0.060) |
| $logEMP_{i,t-1}$ | | | | 0.552*** |
| | | | | (0.017) |
| Firm FE | ✓ | ✓ | ✓ | ✓ |
| Year-Province FE | ✓ | ✓ | ✓ | ✓ |
| Year-Industry FE | ✓ | ✓ | ✓ | ✓ |
| Observations | 21,218 | 21,218 | 19,382 | 19,382 |
| Adjusted $R^2$ | 0.883 | 0.934 | 0.934 | 0.958 |

Table 8: Different Types of Employees

This table presents the results of regressing different types of employees on ETS. *logLOWSKILL* is the logarithm of the number of low-skilled production workers. *LOWSKILL_pct* is the percentage of low-skilled workers to total employees. *logHIGHSKILL* is the logarithm of the number of high-skilled workers. *HIGHSKILL_pct* is the percentage of high-skilled workers to total employees. *logSALEMAN* is the logarithm of the number of salespeople. *SALEMAN_pct* is the percentage of salespeople to total employees. *logADM* is the logarithm of the number of administrative staff. *ADM_pct* is the percentage of the number of administrative staff to total employees. *logRDPerson* is the logarithm of the number of R&D staff. *RDPerson_pct* is the percentage of R&D staff to total employees. See Table 3 for the definitions of the explanatory variables. Standard errors, reported in parentheses, are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

| | $logLOWSKILL_{i,t}$ | | $LOWSKILL\_pct_{i,t}$ | | $logHIGHSKILL_{i,t}$ | | $HIGHSKILL\_pct_{i,t}$ | | $logSALEMAN_{i,t}$ | | $SALEMAN\_pct_{i,t}$ | | $logADM_{i,t}$ | | $ADM\_pct_{i,t}$ | | $logRDPerson_{i,t}$ | | $RDPerson\_pct_{i,t}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) |
| $ETS_{i,t}$ | 0.103*** | 0.098*** | 1.037* | 1.116** | 0.069* | 0.055** | -0.267 | -0.336 | 0.031 | 0.020 | -0.155 | -0.226 | 0.006 | 0.007 | -0.489* | -0.485* | 0.086** | 0.055 | 0.127 | 0.130 |
| | (0.038) | (0.029) | (0.553) | (0.551) | (0.036) | (0.028) | (0.396) | (0.397) | (0.036) | (0.031) | (0.296) | (0.298) | (0.037) | (0.030) | (0.285) | (0.282) | (0.043) | (0.038) | (0.359) | (0.363) |
| $logASSETS_{i,t}$ | | 0.616*** | | -0.438 | | 0.685*** | | 0.688* | | 0.607*** | | 0.064 | | 0.618*** | | -0.551** | | 0.664*** | | 0.309 |
| | | (0.024) | | (0.458) | | (0.027) | | (0.376) | | (0.027) | | (0.263) | | (0.026) | | (0.225) | | (0.032) | | (0.372) |
| $logAGE_{i,t}$ | | 0.501*** | | 4.908 | | 0.247 | | -4.008 | | 0.407** | | -0.696 | | 0.180 | | -3.315 | | -0.073 | | -1.000 |
| | | (0.193) | | (4.045) | | (0.195) | | (2.959) | | (0.205) | | (2.166) | | (0.210) | | (2.182) | | (0.276) | | (3.549) |
| $LEVERAGE_{i,t}$ | | 0.240*** | | 2.463* | | -0.026 | | -2.658** | | 0.111 | | -1.191 | | 0.171** | | 0.743 | | -0.149 | | -3.804*** |
| | | (0.076) | | (1.425) | | (0.077) | | (1.135) | | (0.085) | | (0.844) | | (0.080) | | (0.730) | | (0.094) | | (1.044) |
| $ROA_{i,t}$ | | 0.179 | | 7.318*** | | 0.034 | | 0.797 | | 0.026 | | -0.418 | | -0.321*** | | -3.118*** | | -0.031 | | -0.652 |
| | | (0.116) | | (2.306) | | (0.116) | | (1.656) | | (0.122) | | (1.311) | | (0.113) | | (1.183) | | (0.109) | | (1.202) |
| $CASH_{i,t}$ | | -0.340*** | | -0.787 | | -0.383*** | | -1.116 | | -0.296*** | | 1.500* | | -0.361*** | | 0.173 | | -0.173** | | 0.029 |
| | | (0.066) | | (1.477) | | (0.068) | | (1.028) | | (0.072) | | (0.827) | | (0.076) | | (0.722) | | (0.079) | | (0.826) |
| $TANGIBILITY_{i,t}$ | | 0.785*** | | 11.845*** | | 0.307*** | | -5.607*** | | -0.018 | | -4.740*** | | 0.330*** | | -2.627*** | | 0.526*** | | -2.545** |
| | | (0.097) | | (1.764) | | (0.098) | | (1.489) | | (0.106) | | (1.001) | | (0.095) | | (0.832) | | (0.169) | | (1.289) |
| $GROWTH_{i,t}$ | | 0.014 | | -0.783*** | | 0.027* | | 0.303 | | 0.045*** | | 0.545*** | | 0.035** | | 0.057 | | 0.028* | | -0.321 |
| | | (0.014) | | (0.287) | | (0.015) | | (0.232) | | (0.017) | | (0.170) | | (0.014) | | (0.143) | | (0.016) | | (0.197) |
| $SOE_{i,t}$ | | 0.170*** | | 2.434* | | 0.016 | | -1.014 | | -0.058 | | -0.760 | | 0.084* | | 0.060 | | -0.079 | | -0.110 |
| | | (0.065) | | (1.348) | | (0.056) | | (0.760) | | (0.056) | | (0.653) | | (0.050) | | (0.575) | | (0.049) | | (0.664) |
| $BM_{i,t}$ | | 0.006 | | 0.775 | | -0.040 | | -0.472 | | -0.045 | | 0.107 | | 0.008 | | 0.184 | | -0.039 | | -0.868 |
| | | (0.041) | | (0.789) | | (0.043) | | (0.578) | | (0.047) | | (0.448) | | (0.043) | | (0.377) | | (0.049) | | (0.563) |
| $STKRET_{i,t}$ | | 0.096 | | 6.428* | | -0.206 | | -4.896** | | -0.106 | | -1.316 | | -0.218 | | -2.446 | | -0.066 | | -3.343 |
| | | (0.151) | | (3.323) | | (0.164) | | (2.384) | | (0.187) | | (1.964) | | (0.179) | | (1.710) | | (0.175) | | (2.084) |
| $VOL_{i,t}$ | | -0.100 | | -2.235 | | 0.020 | | 1.600 | | 0.064 | | 1.135 | | -0.071 | | -0.104 | | -0.182* | | -3.049** |
| | | (0.091) | | (2.085) | | (0.104) | | (1.717) | | (0.109) | | (1.111) | | (0.115) | | (1.108) | | (0.109) | | (1.312) |
| Firm FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Year-Province FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Year-Industry FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Observations | 16,485 | 16,485 | 16,485 | 16,485 | 16,790 | 16,790 | 16,790 | 16,790 | 16,183 | 16,183 | 16,183 | 16,183 | 16,681 | 16,681 | 16,681 | 16,681 | 9,770 | 9,770 | 9,706 | 9,706 |
| Adjusted $R^2$ | 0.904 | 0.933 | 0.842 | 0.845 | 0.862 | 0.901 | 0.778 | 0.780 | 0.887 | 0.912 | 0.877 | 0.879 | 0.832 | 0.870 | 0.623 | 0.625 | 0.908 | 0.927 | 0.872 | 0.873 |

Table 9: Political Influence

This table presents the regression results of investment and employment on $SOE$ and $MI$ as proxies for political influence and ETS. $SOE$ equals one if the firm is a state-owned enterprise and 0 otherwise. $MI$ equals zero if the marketization index of the province where the firm's headquarters is located ranks top five in the fiscal year and one otherwise. The ranking of marketization is based on the scores disclosed by Wang, Hu, and Fan (2021). See Table 3 for the definitions of the explanatory variables. Standard errors, reported in parentheses, are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

| Panel A: State-Owned Enterprises | | | | |
|---|---|---|---|---|
| | $logCAPX_{i,t}$ | | $logEMP_{i,t}$ | |
| | $SOE = 0$ | $SOE = 1$ | $SOE = 0$ | $SOE = 1$ |
| | (1) | (2) | (3) | (4) |
| $ETS_{i,t}$ | 0.194*** | 0.084 | 0.034 | 0.098*** |
| | (0.062) | (0.066) | (0.036) | (0.035) |
| Controls | ✓ | ✓ | ✓ | ✓ |
| Firm FE | ✓ | ✓ | ✓ | ✓ |
| Year-Province FE | ✓ | ✓ | ✓ | ✓ |
| Year-Industry FE | ✓ | ✓ | ✓ | ✓ |
| Observations | 11,862 | 7,484 | 11,885 | 7,497 |
| Adjusted $R^2$ | 0.780 | 0.849 | 0.928 | 0.940 |

| Panel B: Marketization Index | | | | |
|---|---|---|---|---|
| | $logCAPX_{i,t}$ | | $logEMP_{i,t}$ | |
| | MI = 0 | MI = 1 | MI = 0 | MI = 1 |
| | (1) | (2) | (3) | (4) |
| $ETS_{i,t}$ | 0.159*** | 0.089 | 0.030 | 0.088*** |
| | (0.061) | (0.065) | (0.042) | (0.031) |
| Controls | ✓ | ✓ | ✓ | ✓ |
| Firm FE | ✓ | ✓ | ✓ | ✓ |
| Year-Province FE | ✓ | ✓ | ✓ | ✓ |
| Year-Industry FE | ✓ | ✓ | ✓ | ✓ |
| Observations | 8,204 | 11,142 | 8,214 | 11,168 |
| Adjusted $R^2$ | 0.828 | 0.816 | 0.936 | 0.941 |

Table 10: Rate-based Allowance Allocation

This table reports the regression results of capture expenditure and employment on the ETS associated with the intensity-based allowance allocation mechanism. $RATEBASE$ is a dummy variable that equals one if the firm is subject to a intensity-based allowance allocation approach and zero otherwise. See Table 3 for the definitions of the explanatory variables. Standard errors, reported in parentheses, are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

| | $logCAPX_{i,t}$ | | $logEMP_{i,t}$ | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $ETS_{i,t}$ | 0.105** | 0.112** | 0.053** | 0.059** |
| | (0.044) | (0.045) | (0.025) | (0.025) |
| $ETS_{i,t} \times RATEBASE_{i,t}$ | 0.239* | 0.240* | 0.107 | 0.104 |
| | (0.126) | (0.129) | (0.096) | (0.097) |
| $RATEBASE_{i,t}$ | 0.018 | -0.053 | 0.157 | 0.163 |
| | (0.257) | (0.276) | (0.201) | (0.215) |
| $logASSETS_{i,t}$ | 1.223*** | 1.239*** | 0.672*** | 0.660*** |
| | (0.034) | (0.037) | (0.018) | (0.019) |
| $logAGE_{i,t}$ | -1.017*** | -1.204*** | 0.353*** | 0.424*** |
| | (0.224) | (0.268) | (0.135) | (0.154) |
| $LEVERAGE_{i,t}$ | -0.361*** | -0.401*** | 0.118** | 0.116* |
| | (0.113) | (0.119) | (0.058) | (0.061) |
| $ROA_{i,t}$ | 1.155*** | 1.243*** | -0.086 | -0.133 |
| | (0.175) | (0.185) | (0.085) | (0.090) |
| $CASH_{i,t}$ | -0.924*** | -0.610*** | -0.353*** | -0.322*** |
| | (0.100) | (0.117) | (0.048) | (0.053) |
| $TANGIBILITY_{i,t}$ | -0.271* | -0.300* | 0.587*** | 0.562*** |
| | (0.152) | (0.158) | (0.076) | (0.077) |
| $GROWTH_{i,t}$ | -0.006 | -0.007 | 0.015 | 0.020* |
| | (0.020) | (0.021) | (0.011) | (0.011) |
| $SOE_{i,t}$ | -0.214** | -0.232** | 0.110** | 0.111** |
| | (0.091) | (0.092) | (0.046) | (0.046) |
| $BM_{i,t}$ | | -0.189*** | | 0.003 |
| | | (0.063) | | (0.033) |
| $SKTRET_{i,t}$ | | -0.841*** | | 0.224* |
| | | (0.274) | | (0.121) |
| $VOL_{i,t}$ | | -0.131 | | -0.175** |
| | | (0.186) | | (0.076) |
| Firm FE | ✓ | ✓ | ✓ | ✓ |
| Year-Province FE | ✓ | ✓ | ✓ | ✓ |
| Year-Industry FE | ✓ | ✓ | ✓ | ✓ |
| Observations | 21,172 | 19,346 | 21,218 | 19,382 |
| Adjusted $R^2$ | 0.807 | 0.814 | 0.934 | 0.934 |

Table 11: Productivity, Efficiency, and Firm Value

This table presents the regression results of productivity, efficiency, and firm value on ETS. See Table 3 for the definitions of the variables. Standard errors, reported in parentheses, are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

| | $logOUTPUT_{i,t}$ | | $TFP_{i,t}$ | | $REVperCapita_{i,t}$ | | $TobinQ_{i,t}$ | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $ETS_{i,t}$ | 0.039* | 0.054* | 0.001 | 0.012 | -0.071 | 0.009 | 0.001 | 0.039 |
| | (0.021) | (0.028) | (0.023) | (0.027) | (0.051) | (0.058) | (0.049) | (0.068) |
| $ETS_{i,t} \times SOE_{i,t}$ | | -0.026 | | -0.022 | | -0.144* | | -0.069 |
| | | (0.036) | | (0.040) | | (0.086) | | (0.082) |
| $SOE_{i,t}$ | 0.045 | 0.047 | 0.016 | 0.018 | 0.036 | 0.045 | -0.210** | -0.205** |
| | (0.038) | (0.038) | (0.036) | (0.036) | (0.054) | (0.054) | (0.103) | (0.104) |
| $logASSETS_{i,t}$ | 0.817*** | 0.816*** | 0.190*** | 0.190*** | 0.113*** | 0.111*** | -1.099*** | -1.099*** |
| | (0.019) | (0.019) | (0.017) | (0.017) | (0.031) | (0.031) | (0.048) | (0.048) |
| $logAGE_{i,t}$ | 0.316** | 0.312** | 0.147 | 0.144 | -0.183 | -0.204 | -0.073 | -0.084 |
| | (0.123) | (0.124) | (0.129) | (0.129) | (0.287) | (0.287) | (0.317) | (0.317) |
| $LEVERAGE_{i,t}$ | 0.096 | 0.095 | 0.157*** | 0.157*** | 0.094 | 0.091 | 0.173 | 0.172 |
| | (0.060) | (0.060) | (0.059) | (0.059) | (0.121) | (0.121) | (0.141) | (0.141) |
| $ROA_{i,t}$ | 1.038*** | 1.038*** | 1.019*** | 1.019*** | 0.951*** | 0.951*** | 1.878*** | 1.878*** |
| | (0.094) | (0.094) | (0.088) | (0.088) | (0.165) | (0.165) | (0.285) | (0.285) |
| $CASH_{i,t}$ | -0.226*** | -0.226*** | 0.032 | 0.033 | 0.158* | 0.161* | 0.216 | 0.218 |
| | (0.053) | (0.053) | (0.050) | (0.050) | (0.095) | (0.095) | (0.151) | (0.151) |
| $TANGIBILITY_{i,t}$ | 0.339*** | 0.340*** | -0.392*** | -0.391*** | -0.487*** | -0.486*** | -0.374** | -0.373** |
| | (0.074) | (0.074) | (0.072) | (0.072) | (0.129) | (0.129) | (0.175) | (0.175) |
| $GROWTH_{i,t}$ | 0.182*** | 0.182*** | 0.159*** | 0.159*** | 0.197*** | 0.198*** | -0.001 | -0.001 |
| | (0.011) | (0.011) | (0.013) | (0.013) | (0.025) | (0.025) | (0.027) | (0.027) |
| $BM_{i,t}$ | -0.171*** | -0.171*** | -0.150*** | -0.149*** | -0.185*** | -0.182*** | | |
| | (0.033) | (0.033) | (0.033) | (0.033) | (0.060) | (0.060) | | |
| $SKTRET_{i,t}$ | -0.302** | -0.303** | -0.312*** | -0.313*** | -0.356* | -0.357* | 13.231*** | 13.227*** |
| | (0.125) | (0.125) | (0.121) | (0.121) | (0.212) | (0.212) | (0.368) | (0.368) |
| $VOL_{i,t}$ | -0.260*** | -0.258*** | -0.144** | -0.143** | -0.368*** | -0.361*** | 0.477* | 0.480* |
| | (0.075) | (0.075) | (0.072) | (0.073) | (0.126) | (0.127) | (0.254) | (0.254) |
| Firm FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Year-Province FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Year-Industry FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Observations | 18,547 | 18,547 | 16,901 | 16,901 | 19,382 | 19,382 | 19,382 | 19,382 |
| Adjusted $R^2$ | 0.962 | 0.962 | 0.824 | 0.824 | 0.732 | 0.732 | 0.778 | 0.778 |

Table 12: Employee Wage

This table reports the regression results of employee wage on ETS. *logWAGES* is the logarithm of total salaries received by all employees, including executives and directors. *logAWAGES* is the logarithm of average salaries received by all employees. *logEWAGES* is the logarithm of average salaries received by employees, excluding executives and directors. *logMWAGES* is the logarithm of average salaries received by executives and directors. See Table 3 for the definitions of the explanatory variables. Standard errors, reported in parentheses, are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

| | $logWAGES_{i,t}$ | | $logAWAGES_{i,t}$ | | $logEWAGES_{i,t}$ | | $logMWAGES_{i,t}$ | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $ETS_{i,t}$ | 0.029 | 0.047* | -0.025 | 0.011 | -0.028* | 0.009 | -0.014 | 0.036 |
| | (0.019) | (0.028) | (0.017) | (0.023) | (0.017) | (0.024) | (0.020) | (0.030) |
| $ETS_{i,t} \times SOE_{i,t}$ | | -0.032 | | -0.064** | | -0.068** | | -0.090** |
| | | (0.033) | | (0.031) | | (0.030) | | (0.037) |
| $SOE_{i,t}$ | 0.100*** | 0.102*** | 0.005 | 0.009 | 0.007 | 0.012 | -0.036 | -0.030 |
| | (0.034) | (0.034) | (0.032) | (0.032) | (0.033) | (0.033) | (0.034) | (0.034) |
| $logASSETS_{i,t}$ | 0.709*** | 0.708*** | 0.035*** | 0.034*** | 0.035*** | 0.034** | 0.226*** | 0.225*** |
| | (0.017) | (0.017) | (0.013) | (0.013) | (0.013) | (0.013) | (0.013) | (0.013) |
| $logAGE_{i,t}$ | 0.479*** | 0.474*** | 0.051 | 0.041 | 0.064 | 0.054 | -0.092 | -0.105 |
| | (0.122) | (0.122) | (0.105) | (0.105) | (0.106) | (0.107) | (0.120) | (0.120) |
| $LEVERAGE_{i,t}$ | 0.029 | 0.029 | -0.043 | -0.044 | -0.034 | -0.035 | -0.222*** | -0.224*** |
| | (0.052) | (0.052) | (0.044) | (0.044) | (0.044) | (0.044) | (0.046) | (0.046) |
| $ROA_{i,t}$ | -0.031 | -0.031 | 0.087 | 0.087 | 0.092 | 0.092 | 0.672*** | 0.672*** |
| | (0.081) | (0.081) | (0.068) | (0.068) | (0.070) | (0.069) | (0.071) | (0.071) |
| $CASH_{i,t}$ | -0.255*** | -0.255*** | 0.061 | 0.062 | 0.045 | 0.046 | -0.058 | -0.056 |
| | (0.045) | (0.045) | (0.040) | (0.040) | (0.040) | (0.040) | (0.043) | (0.043) |
| $TANGIBILITY_{i,t}$ | 0.435*** | 0.435*** | -0.126** | -0.125** | -0.115** | -0.115** | -0.168*** | -0.168*** |
| | (0.064) | (0.064) | (0.053) | (0.053) | (0.054) | (0.054) | (0.049) | (0.049) |
| $GROWTH_{i,t}$ | 0.013 | 0.013 | -0.003 | -0.003 | -0.004 | -0.004 | -0.040*** | -0.040*** |
| | (0.009) | (0.009) | (0.008) | (0.008) | (0.008) | (0.008) | (0.009) | (0.009) |
| $BM_{i,t}$ | -0.067** | -0.066** | -0.067*** | -0.066*** | -0.068*** | -0.067*** | -0.199*** | -0.197*** |
| | (0.030) | (0.030) | (0.025) | (0.024) | (0.025) | (0.025) | (0.025) | (0.025) |
| $SKTRET_{i,t}$ | -0.213* | -0.214* | -0.468*** | -0.468*** | -0.476*** | -0.477*** | -0.508*** | -0.509*** |
| | (0.112) | (0.112) | (0.099) | (0.099) | (0.102) | (0.102) | (0.101) | (0.101) |
| $VOL_{i,t}$ | -0.071 | -0.069 | 0.093 | 0.096 | 0.086 | 0.090 | 0.011 | 0.016 |
| | (0.067) | (0.067) | (0.061) | (0.061) | (0.063) | (0.063) | (0.068) | (0.068) |
| Firm FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Year-Province FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Year-Industry FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Observations | 19,381 | 19,381 | 19,381 | 19,381 | 19,347 | 19,347 | 19,360 | 19,360 |
| Adjusted $R^2$ | 0.960 | 0.960 | 0.755 | 0.755 | 0.750 | 0.750 | 0.810 | 0.810 |

Table 13: Robustness Checks

This table reports the results of the robustness checks. Column (1) and (6) are for the PSM sample constructed based on the matching outcome of pre-treatment data at the end of 2012. Column (2) and (7) are for the PSM sample constructed based on the matching outcome of pre-treatment data from 2009 to 2012. Column (3) and (8) are for the sample of all industries. Column (4) and (9) are for the sample, excluding treated firms covered by the national ETS. Column (5) and (10) are for $ETS\_Intensity$ as the key explanatory variable. $ETS\_Intensity$ is defined as the number of times of which different ETS pilots cover a listed firm in a year. See Table 3 for the definitions of the explanatory variables. Standard errors, reported in parentheses, are clustered at the firm level. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

| | $logCAPX_{i,t}$ | | | | | $logEMP_{i,t}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| $ETS_{i,t}$ | 0.154** | 0.092* | 0.120*** | 0.123** | | 0.064** | 0.069** | 0.065** | 0.070** | |
| | (0.064) | (0.055) | (0.045) | (0.051) | | (0.032) | (0.028) | (0.027) | (0.032) | |
| $ETS\_Intensity_{i,t}$ | | | | | 0.005* | | | | | 0.007** |
| | | | | | (0.003) | | | | | (0.003) |
| $logASSETS_{i,t}$ | 1.241*** | 1.271*** | 1.228*** | 1.237*** | 1.239*** | 0.633*** | 0.622*** | 0.685*** | 0.659*** | 0.661*** |
| | (0.055) | (0.046) | (0.031) | (0.037) | (0.037) | (0.034) | (0.030) | (0.020) | (0.019) | (0.019) |
| $logAGE_{i,t}$ | -1.979*** | -1.600*** | -1.430*** | -1.212*** | -1.231*** | 0.016 | 0.623** | 0.396** | 0.421*** | 0.414*** |
| | (0.512) | (0.464) | (0.263) | (0.268) | (0.269) | (0.288) | (0.258) | (0.156) | (0.154) | (0.154) |
| $LEVERAGE_{i,t}$ | -0.349 | -0.355** | -0.577*** | -0.400*** | -0.395*** | 0.181 | 0.149 | 0.061 | 0.116* | 0.118* |
| | (0.218) | (0.178) | (0.117) | (0.119) | (0.120) | (0.126) | (0.096) | (0.068) | (0.061) | (0.061) |
| $ROA_{i,t}$ | 1.702*** | 1.155*** | 1.153*** | 1.247*** | 1.248*** | -0.119 | -0.320** | -0.032 | -0.131 | -0.131 |
| | (0.349) | (0.285) | (0.173) | (0.185) | (0.184) | (0.190) | (0.143) | (0.090) | (0.090) | (0.090) |
| $CASH_{i,t}$ | -0.809*** | -0.720*** | -0.503*** | -0.604*** | -0.592*** | -0.435*** | -0.327*** | -0.198*** | -0.319*** | -0.315*** |
| | (0.203) | (0.187) | (0.113) | (0.117) | (0.117) | (0.108) | (0.092) | (0.058) | (0.053) | (0.053) |
| $TANGIBILITY_{i,t}$ | -0.649*** | -0.437* | 0.361** | -0.301* | -0.301* | 0.303** | 0.380*** | 0.832*** | 0.560*** | 0.559*** |
| | (0.238) | (0.226) | (0.154) | (0.158) | (0.158) | (0.134) | (0.109) | (0.083) | (0.077) | (0.077) |
| $GROWTH_{i,t}$ | -0.069 | -0.055 | -0.006 | -0.007 | -0.008 | -0.006 | 0.035* | 0.009 | 0.020* | 0.020* |
| | (0.043) | (0.040) | (0.016) | (0.021) | (0.021) | (0.029) | (0.021) | (0.008) | (0.011) | (0.011) |
| $SOE_{i,t}$ | 0.024 | -0.006 | -0.269*** | -0.235** | -0.235** | 0.038 | 0.113* | 0.089* | 0.109** | 0.109** |
| | (0.150) | (0.131) | (0.083) | (0.092) | (0.092) | (0.076) | (0.058) | (0.049) | (0.046) | (0.046) |
| $BM_{i,t}$ | -0.279*** | -0.272*** | -0.258*** | -0.184*** | -0.181*** | -0.008 | 0.009 | -0.042 | 0.006 | 0.005 |
| | (0.098) | (0.085) | (0.060) | (0.063) | (0.063) | (0.060) | (0.047) | (0.033) | (0.033) | (0.033) |
| $STKRET_{i,t}$ | -1.323** | -1.193*** | -1.127*** | -0.820*** | -0.808*** | 0.367 | 0.421** | 0.136 | 0.234* | 0.231* |
| | (0.543) | (0.454) | (0.262) | (0.274) | (0.274) | (0.249) | (0.190) | (0.120) | (0.122) | (0.122) |
| $VOL_{i,t}$ | -0.267 | -0.081 | -0.141 | -0.135 | -0.152 | -0.195 | -0.034 | -0.209*** | -0.175** | -0.182** |
| | (0.396) | (0.312) | (0.181) | (0.186) | (0.186) | (0.185) | (0.126) | (0.081) | (0.076) | (0.076) |
| Firm FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Year-Province FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Year-Industry FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Observations | 4,770 | 6,490 | 26,424 | 19,346 | 19,346 | 4,773 | 6,496 | 26,481 | 19,382 | 19,382 |
| Adjusted $R^2$ | 0.796 | 0.805 | 0.802 | 0.814 | 0.814 | 0.928 | 0.936 | 0.918 | 0.934 | 0.934 |