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

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Abstract

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 investment and expanded production workforce, while their climate decisions are influenced by state ownership and regional heterogeneity.

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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

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

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:

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

where j represents the jth pre-treatment year, and k represents the kth 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.]

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