Department of Land Economy
Environment, Law & Economics

UNIVERSITY OF CAMBRIDGE
Real Estate Research Centre

**Working Paper**
**Series No. 2024-01**

**Title:** When the cat is away the mice will not play:
The political economy of carbon emission trading systems

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# When the cat is away the mice will not play:
# The political economy of carbon emission trading systems

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## Abstract

We examine how carbon emission trading systems (ETS) address both government and market failures in the Cat and Mouse game of controlling emissions. We investigate how Chinese cities responded to two natural experiments: unannounced inspections by the central government and turnovers of senior local government officials. Using both theoretical and empirical analysis, we show that cities tend to rein in their emissions when inspection teams are in town because "the cat is around." And they are less stringent on emission controls when local political powers change hands because "the cat is away". However, cities with ETS exchanges will be less responsive to these political events than those without, as the ETS system regulates firms' behaviour and consequently reduces both the incentives and opportunities for gaming the system. Our theoretical model indicates an efficient Carbon Market condition when the price is high enough. And empirical works confirms the essentiality of the condition. The findings remain robust when alternative event windows and estimation methods are employed. We conclude that ETS is an effective way to address government and market failures in carbon emission control. When the cat is away, the mice will not play because there is a system in place to discourage such behaviour. Our findings provide additional support for the development of ETS in China and beyond.

**Keywords**: Carbon emission control; Pilot ETS in China; political risk; climate policy; global warming; cap-and-trade; government failure and market failure

**JEL Classifications**: C32; E44; G12; O13; P28

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# When the cat is away the mice will not play:
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## 1. Introduction

Carbon emission trading systems (ETS) have emerged as a prominent policy tool for controlling greenhouse gas emissions, as they combine market incentives with policy targets. These systems have been widely adopted and proven effective in several regions, including the European Union, the United States and China. Existing studies on ETS have provided valuable insights into the design, implementation (Munnings et al., 2016; Narassimhan et al., 2018; Zhang et al., 2014), and effectiveness of these market-based instruments in reducing greenhouse gas emissions (Hu et al., 2020; Liu et al., 2017; Liu et al., 2018). However, a gap in the literature remains, particularly in the context of China, where the interaction between political events and the functioning of ETS has not been extensively explored.

In reality, emissions control is always a Cat and Mouse game between regulators and polluters. Before the application of Carbon ETS, the government mostly relies on normal regulations which are imperfect and inefficient as the growth of emissions. Carbon ETS emerged with a systematic monitoring system and market structure which shocked the players in the game when invented (Greenstone et al.2022). However, political shocks are never absent even in such a market. For example, Zheng and Na (2020) found that unannounced environmental inspections in China temporarily improved air quality, indicating that local governments tightened regulations under central oversight. However, pollution rebounded once inspections ended as compliance waned. Moreover, the possible discontinuity of government policy is always a concern for emission control in the world. Our question is: How could political uncertainty influence carbon emissions? And what is the role of Carbon ETS in such a world with political uncertainty?

In this study, we investigate how carbon emissions in Chinese cities responded to two symmetric natural experiments: unannounced inspections by the central government and turnovers of senior local government officials. We hypothesize that cities tend to rein in their emissions when inspection teams are present, as existing literature indicated(Zheng and Na 2020), since officials are more likely to enforce environmental regulations when "the cat is around." Conversely, cities may be less stringent on emission controls when local political powers change hands, as officials are preoccupied with more pressing issues during these critical periods of their political careers. This phenomenon can be described as "the cat is away." Our theoretical model describes the mechanism of such a Cat and Mouse Game in carbon emission controls. Besides, it predicts that cities with ETS exchanges will be less responsive to these political events than those without, as the ETS system regulates firms' behaviour and consequently reduces both the incentives and opportunities for gaming the system. Finally, the model also implies that the Carbon ETS market will address both government failure and market failure when the carbon price is high enough—which we conclude it as an Efficient Carbon Market Condition.

To test the hypothesis and the conclusion of the model, we first employ a difference-in-differences approach using daily data from 2013 to 2019 across 270 cities in 31 provinces in China. Our empirical findings consistently support the hypothesis and literature that air quality improved during inspections which is consistent with existing literature. Specifically, we also recorded a 2.2% emission increase when there were turnovers of local government leaders. The discontinuity of turnovers' effect on air quality effect is further confirmed by RD estimate.

However, these effects were significantly weaker in cities with an ETS exchange. Using samples of both cities with Carbon ETS and regions covered by Carbon ETS, we find a significant moderate effect of Carbon ETS on both inspections and turnovers. Carbon ETS provides a 5% moderate effect for regions covered by ETS and a 9% moderate effect for cities with ETS which makes those cities avoid air quality turbulence during turnovers. Therefore, the presence of a carbon market helps to mitigate the impact of political uncertainty on emissions control efforts. The results remain robust when alternative event windows and estimation methods are employed.

Carbon ETS will not always be efficient. As our model indicates, it only addresses failures under the Efficient Carbon Market condition. Using the daily carbon price of local ETS, we explore how carbon prices address government and market failure. We find a higher carbon price provides a stronger moderate effect on political uncertainty. Moreover, higher carbon prices do improve air quality. The results remain robust when we use different forms of carbon price indicators to address the concern about reverse causality. Since price signals the situation of market operation ,our analysis reinforces the conclusion that ETS markets help to stabilize emissions control efforts in the face of political uncertainty.

Our study provides valuable insights into the potential of ETS to address both government and market failures in carbon emission control. The findings suggest that, even when the cat is away, the mice will not play because the ETS system is in place to discourage opportunistic behaviour. This has important implications for the development of ETS in China and other developing countries, where political factors can exert a significant influence on the effectiveness of environmental policies. Furthermore, our research highlights the need for a more comprehensive understanding of the interplay between political economy factors and carbon markets. Future research could extend our findings by exploring how ETS interacts with other policy instruments, as well as investigating the distributional consequences of ETS implementation in developing countries. By shedding light on these issues, this study aims to contribute to the ongoing debate on the optimal design and implementation of carbon ETS, ultimately informing the global effort to mitigate climate change.

## 2. Institutional Background

### *2.1 Carbon emission trading systems*

The concept of carbon emission trading systems has its roots in market-based environmental policies and emerged in the late 20th century. These systems gained prominence after the Kyoto Protocol of 1997, which introduced the idea of emissions trading as a flexible mechanism to reduce greenhouse gas emissions cost-effectively. The European Union launched the world's first and largest carbon market, the EU Emissions Trading System (EU ETS), in 2005, setting the stage for the proliferation of similar trading schemes around the globe. Over the years, various jurisdictions have implemented their own carbon trading systems, adopting different designs and scopes to suit their respective contexts.

Carbon emission trading systems (ETS) are market-based mechanisms designed to reduce greenhouse gas emissions cost-effectively. The primary mechanism underpinning ETS is the cap-and-trade system. Under this system, a regulatory authority sets a cap on the total allowable emissions for specific sectors or regions. The cap is then divided into allowances, which represent the right to emit a certain amount of greenhouse gases. These allowances are allocated to regulated entities, such as firms, either freely or through auctions.

Once allowances have been allocated, a market for trading them emerges. Firms that can reduce their emissions more cheaply than the market price of allowances have an incentive to do so, and sell their surplus allowances to firms facing higher abatement costs. This process enables the market to find the most cost-effective solutions for achieving the overall emissions reduction target. The World Bank's "State and Trends of Carbon Pricing" report provides a comprehensive overview of the mechanisms and status of carbon pricing initiatives worldwide, including emission trading systems (World Bank, 2022).

The price of allowances in an ETS is determined by various factors, such as the stringency of the cap, economic growth, technological advancements, fuel prices, and weather patterns. Policy design features, like the presence of a price floor or ceiling, can also impact allowance prices. The European Environment Agency's "Trends and Projections in Europe" report offers insights into the factors that influence allowance prices within the context of the EU ETS (European Environment Agency, 2022).

Carbon emission trading systems have potential applications in both developed and developing countries. In developing countries, ETS can offer several advantages, such as the potential to mobilise domestic and international financial resources for climate action, drive innovation, and support sustainable development. However, the effectiveness of ETS in developing countries can be influenced by a range of factors, including the quality of institutions, market infrastructure, and regulatory capacity. Moreover, the distributional impacts of ETS on vulnerable populations should be carefully considered, ensuring that any potential regressive effects are mitigated through appropriate policy design.

One of the key challenges in implementing ETS in developing countries is the lack of reliable emissions data, which is crucial for setting caps, allocating allowances, and monitoring compliance. Capacity building in the areas of emissions monitoring, reporting, and verification can help address this challenge. International cooperation and knowledge sharing, such as the Partnership for Market Readiness (PMR) led by the World Bank, can also play a crucial role in assisting developing countries in the design and implementation of ETS.

In conclusion, carbon emission trading systems provide a market-based mechanism for achieving emissions reductions cost-effectively. The price of allowances is influenced by various factors, including policy design and external market conditions. While ETS has potential applications in developing countries, careful consideration of institutional capacity, market infrastructure, and distributional impacts is necessary to ensure their effectiveness and equitable outcomes.

### *2.2 Carbon emission trading systems in China*

Carbon emission trading systems in China have experienced rapid development in recent years, playing a crucial role in the nation's efforts to tackle climate change and reduce greenhouse gas emissions. This section provides a brief overview of China's carbon emission trading market, the regulatory framework and key policies, as well as challenges and opportunities specific to the Chinese context.

China's ETS journey began in 2011 when the National Development and Reform Commission (NDRC) approved pilot ETS programs in seven provinces and cities (Jiang et al., 2016; Zhang et al., 2014) Seven regional markets, including Beijing, Shanghai, Guangdong, and Shenzhen, were established to explore and refine market-based approaches to curbing emissions. These pilot programs cover multiple sectors, such as power, cement, steel, and aviation. Moreover, these pilot schemes provided valuable insights and experiences, which informed the design of China's national carbon market. In 2017, the Chinese government announced the launch of its national Emissions Trading System (ETS), initially covering the power sector and gradually expanding to include other major emitting industries. As of 2021, China's ETS is the largest carbon market globally, covering over 2,000 power plants and accounting for around 14% of the country's total emissions. As the world's largest greenhouse gas emitter, China's commitment to developing an effective carbon market is critical for the global effort to mitigate climate change.

The Ministry of Ecology and Environment (MEE) is the primary regulator responsible for China's ETS, overseeing market operations, compliance, and policy development. Key policies include the "Work Plan for the Construction of the National Carbon Emission Trading Market in the Power Generation Industry" [2] and the "Administrative Measures for Carbon Emission Trading" [3] , which provide guidelines for market operation, allowance allocation, and compliance. China's ETS faces several challenges, such as data quality and transparency, limited market liquidity, and the need for more robust MRV (Monitoring, Reporting, and Verification) systems (Zhang et al., 2014). Addressing these challenges will be crucial for the long-term success of China's ETS. On the other hand, the sheer size of China's market presents significant opportunities for innovation and learning, both domestically and internationally. China's ETS can also contribute to achieving the country's climate targets, such as reaching peak emissions before 2030 and achieving carbon neutrality by 2060 (IEA, 2021).

## 3. Literature Review and Hypothesis

### *3.1 The role of political economy in climate change mitigation, carbon emission reduction, and sustainable development*

Political economy factors, such as geopolitical dynamics, national interests, and distributional concerns, play a crucial role in shaping the global response to climate change mitigation, carbon emission reduction, and sustainable development.

The political economy of climate change mitigation is largely driven by the need to balance global cooperation with national interests (Goldthau and Sovacool, 2012; Keohane and Victor, 2011). International agreements such as the Paris Agreement require countries to commit to reducing greenhouse gas emissions, but domestic politics and economic factors often influence the ambition and implementation of these commitments. Carbon emission reduction policies are also shaped by the political economy context. Countries face trade-offs between environmental goals, economic growth, and social equity, which influence the choice and effectiveness of policy instruments such as carbon pricing and renewable energy subsidies (Meckling, 2011). Moreover, the geopolitical context can have a significant impact on carbon reduction efforts, as demonstrated by the net increase of greenhouse gas, equivalent to the annual output of a country such as Belgium, triggered by the first 12 month of the Ukraine war[4]. This example underscores the need to consider how global power dynamics and national

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[2] https://www.ndrc.gov.cn/xxgk/zcfb/ghxwj/201712/W020190905495689305648.pdf

[3] https://www.mee.gov.cn/xxgk2018/xxgk/xxgk02/202101/t20210105_816131.html

[4] https://www.reuters.com/world/accounting-war-ukraines-climate-fallout-2023-06-06/

security concerns influence countries' approach to carbon emission reduction (Dolšak and Prakash, 2018).

Moreover, geopolitical events, such as the Ukrainian war and the Israeli–Palestinian conflict, can significantly alter countries' attitudes towards climate change and sustainable development goals. For instance, Russia's invasion of Ukraine hastened the EU's plan for renewable energy supply but also reminded EU countries of "energy independence".[5] These events highlight the intricate interconnections between politics, economics, and environmental challenges, demonstrating the importance of considering political economy factors in understanding and addressing climate change, carbon emission reduction, and sustainable development.

### *3.2 Political events and their effects on environmental policies*

Several studies have highlighted the influence of political factors on environmental outcomes. For example, Patnaik (2019) shows how the ideology of government actors and the electoral cycle and the type of prevalent bureaucratic regulatory system can shape environmental policies in the EU. In the Chinese context, Zheng and Na (2020) examined the effects of unannounced inspections by the central government on air pollution levels, concluding that cities significantly reduced their emissions during these inspections. Persistent tensions between decentralized and centralized imperatives generate cycles in environmental and energy systems governance in China Alkon and Wong (2020). These studies suggest that political events can shape the enforcement and effectiveness of environmental policies.

Another stream of research has focused on the role of political turnover in environmental policy enforcement. For instance, Tian and Tian (2021) found a significant relationship exists between the political incentives of city officials and environmental pollution during the Provincial Communist Party Congresses, when new leadership for the party committee is determined. There is an environmental political business cycle in which pollution increases in years leading to the year of leader turnover when local leaders lessen the enforcement of environmental regulations to reduce local industries' production costs and/or to attract firms from other jurisdictions (Cao et al., 2019). Similarly, Wu et al. (2013) discovered that political turnover in Chinese provinces led to increased energy consumption and CO2 emissions, indicating a potential trade-off between political stability and environmental outcomes.

Despite these contributions, the existing literature has not fully addressed the interplay between political events and environmental policies in the context of carbon emission trading markets. In China, the relationship between political events, such as unannounced inspections and political turnover, and the effectiveness of ETS remains underexplored. This gap presents an opportunity for further research on how the dynamics of political uncertainty might affect the functioning of carbon markets in China and the potential role of ETS in mitigating the impact of political events on environmental outcomes.

### *3.3 Efficacy of carbon emission trading systems*

ETS, as a market-based instrument, effectively addresses government and market failures in carbon emission control by harnessing the power of market incentives and aligning them with policy targets. The flexibility, adaptability, and innovation-driven nature of ETS, coupled with

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[5] https://www.chathamhouse.org/2023/09/consequences-russias-war-ukraine-climate-action-food-supply-and-energy-security/04-upended

its potential to foster international cooperation, make it a powerful tool for achieving emission reduction goals in an efficient and equitable manner. Evidence shows that ETS creates a price signal for carbon emissions, internalising the environmental costs associated with emitting greenhouse gases. By putting a price on carbon, ETS encourages firms to reduce their emissions in the most cost-efficient manner (Munnings et al., 2016), fostering innovation and investments in low-carbon technologies (Chen et al., 2021; Ren et al., 2020; Zhu et al., 2019).

Moreover, ETS can be adapted over time to reflect changing policy goals, market conditions, or scientific knowledge, ensuring that the policy remains relevant and effective in addressing the evolving challenge of climate change (Ellerman et al., 2016). ETS has the potential to facilitate international cooperation and policy harmonisation, helping to address the global nature of climate change. The EU ETS, for example, has inspired the development of carbon markets in other regions and provided a model for international policy coordination (Tuerk et al., 2009). By linking carbon markets across different jurisdictions, ETS can help to achieve global emission reduction targets in a more cost-effective and equitable manner (Hintermann et al., 2016).

The European Union ETS, as the world's largest and longest-running carbon market, has attracted substantial research attention. For instance, Ellerman et al. (2016) provided an in-depth analysis of the EU ETS, assessing its performance in terms of environmental effectiveness, cost efficiency, and distributional equity. They found that the EU ETS led to a 10% reduction in emissions within regulated sectors during the 2008-2016 period. Calel and Dechezlepretre (2016) analysed the impact of the EU ETS on technological innovation, demonstrating that the policy stimulated patenting activity in low-carbon technologies. Martin et al. (2016) examined the role of the EU ETS in shaping corporate investment behaviour, finding evidence of increased investments in energy efficiency and low-carbon technologies.

Several studies have offered a global outlook on ETS design and implementation, comparing different carbon markets and drawing lessons for future policy development (Hintermann et al., 2016; Narassimhan et al., 2018; Tuerk et al., 2009; Xiong et al., 2017). The Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade program in the Northeastern United States, has been successful in reducing emissions (Murray and Maniloff, 2015). The California Cap-and-Trade Program has played a significant role in reducing the state's greenhouse gas emissions (Cushing et al., 2018; Woo et al., 2017; Woo et al., 2018). Maybe necessary to discuss the leakage controversy if there is space (Caron et al., 2015).

As new carbon markets emerge in other regions, researchers have increasingly focused on these developing ETS. For example, Duan et al. (2014) reviewed the design and implementation of China's pilot ETS, highlighting the challenges in ensuring equitable distribution of permits and improving market efficiency. China's seven pilot ETS have demonstrated potential for reducing emissions. A study by Qi et al. (2018) in Applied Energy found that the pilot schemes led to a 3-5% reduction in CO2 emissions in regulated industries between 2013 and 2015. However, the study also highlighted the need for improvements in the allocation of allowances and the coverage of sectors.

### *3.4 Carbon ETS Market: Market Failure and Government Failure*

The perennial debate on the balance between government intervention and free markets lies at the heart of economic growth considerations. Over the years, evidence has emerged highlighting the intricacies of market and government failures. Early discussion on market failure ( Stiglitz, 1989;Datta-Chaudhuri, 1990) and government failure( Datta-Chaudhuri, 1990; Krueger (1990)urged to identify the source of failure and striking a delicate balance between market and government interventions (Stiglitz, 1989). In the pursuit of balance, scholars have explored innovative approaches like systems competition(Sinn 1997) and social norms(Agell 1999).

New challenges emerged as the 2008 financial crisis prompted a reassessment of government intervention. Stiglitz (2008) advocates for a nuanced regulatory approach using a mix of instruments to mitigate government failure risks, including disclosure requirements, ownership restrictions, and behavioral constraints. Cole (2009) illustrates how government-owned banks in India, driven by electoral interests, exhibit political capture, resulting in costly political interference and limited agricultural output increases. Tirole (2012) discusses optimal government intervention in the credit market, emphasizing the delicate balance needed to restart trading without eliminating adverse selection entirely. Recent studies also have scrutinized market failures in specific contexts, such as the kidney exchange system (Agarwal et al., 2019),the adoption of irrigation in underdeveloped countries (Jones et al., 2022), and workers' compensation insurance market(Cabral et al. 2022).

Specifically, market failure and government failure have always been a key issue in discussing optimal climate policy. In the early stages of carbon ETS development, Atkinson and Tietenberg (1991) scrutinized the EPA's emissions trading program, revealing significant market failures. These included the program's inability to execute some cost-effective trades violating air quality standards, a rigid constant emissions rule, and suboptimal early trades. Building on this, Andrew (2008) depicted climate change and greenhouse gas emissions as an extreme case of market failure persisting for over two centuries. The author specifically highlighted failure within the EU Emissions Trading Scheme (ETS), citing generous emissions allocations by states undermining the carbon price, exclusions of certain industries and gases, and instances of fraud due to information gaps, which exemplifies a system prone to both market and government failures. Newell (2012) delved into issues surrounding carbon markets, specifically scrutinizing the Clean Development Mechanism (CDM) under the Kyoto Protocol. The author identified problems such as fraud, gaming, and a lack of additionality of emissions reductions, emphasizing that these were but rooted in deeper political economy issues.

Since the 2010s, the global development of carbon ETS has accelerated, guided by both government and market efforts. Paterson (2012) argued that standard rationale and efficiency arguments did not wholly explain the rapid adoption of carbon markets. Instead, the author provided a political economy analysis, emphasizing the delicate balance between the power of government and market forces in enabling investment/profit cycles and coalition-building to drive climate policy.

As global cooperation intensifies to address carbon emissions, Governments, tasked with drawing agreements on carbon emission plans, grapple with developing models of the social cost of carbon under controversy. Pindyck (2013) criticized Integrated Assessment Models (IAMs) for their unreliability in estimating the social cost of carbon, suggesting a focus on plausible catastrophic outcome scenarios and their welfare impacts to inform stringent emission abatement policies. Stern and Stiglitz (2021) argued that IAMs typically focus only on the market failure associated with greenhouse gas emissions, neglecting other critical failures like innovation spillovers and financial market risks. The paper critiqued the assumption in IAMs that governments can perfectly correct market failures and redistribute income.

In summary, climate policy serves as a compelling and optimal case for understanding the intricate interplay of government and market failures. From addressing emissions trading challenges to navigating broader global cooperation issues, policymakers face the complexities inherent in effectively tackling climate change. Since the concepts of "market failure" and "government failure" are inherently intertwined(Nedergaard 2006; Furton and Martin 2019 ), policymakers must adeptly recognize the inevitable systemic changes associated with decarbonization, involving disruption, disequilibria, and policy coordination challenges (Stern, 2022; Stern and Stiglitz, 2021).

### *3.5 Gaps in the literature & development of hypotheses*

Existing research on carbon emission trading systems (ETS) has made significant contributions to our understanding of their design, implementation, and effectiveness. While many studies have assessed the technical aspects of ETS design and their impact on emissions reduction (e.g., Ellerman et al., 2016; Qi et al., 2018), Your paper, which focuses on the impact of political uncertainty on carbon emission trading systems in China, can contribute to filling this gap.

Moreover, although there are several studies on individual ETS (e.g., California Air Resources Board, 2019; Zhang et al., 2014), comparative analyses across different jurisdictions and systems are relatively limited (e.g., Egenhofer et al., 2011). Such research could provide valuable insights into the factors that determine the success or failure of ETS and inform policy design and implementation. By examining the Chinese ETS market as a whole and also investigating trading activities within four largest ETS markets in China, this paper could contribute to the development of a more comprehensive understanding of ETS in different contexts.

Based on the above discussions, we derive two hypotheses as follows.

Hypothesis 1: Cities reduce/increase carbon emissions during inspections/turnovers
Hypothesis 2: Carbon emissions in Cities with ETS are less responsive to inspections and turnovers

## *4.* The Model

### *4.1 Firms and Regulations*

A small economy has a polluting sector that produces a good x This economy consists of consumers and polluting firms, with the population normalized to 1. Consumers experience disutility due to pollution associated with local firms' production. A representative consumer's utility function is given by:

$$U = u(c^x) - \theta(H)(X) \tag{1}$$

where $c^x$ is consumption of the good x and unregulated production g(x), with domestic prices equal to p. $u(c^x)$ is a strictly concave and differentiable sub-utility function. Production of x by each of the $n$ identical firms is given by $x_i$, where $nx_i = X$. $\theta$ is per-unit damage, which depends on the $H = nh_i$ spent by the firms on pollution control, where $\theta_h < 0$ and$\theta_{hh} > 0.0$. Thus, $\theta(H)$represents aggregate emissions damage level. Besides, the consumer surplus for consuming good x is $\omega(x)$.

Good "x" is produced with a constant marginal cost equal to one. The cost of producing good "x" is given by $v(x, h)$, with the assumptions $v_x > 0, v_h > 0$ . In addition to production costs, firms are regulated based on a carbon emission reduction plan. The regulation cost Δ incurred on observing the carbon emission reduction plan is:

$$\Delta(\theta_t, x_t, x_{t-1}, \varepsilon_t, \zeta_t) = \zeta_t(\theta_t x_t - \varepsilon_t x_{t-1})$$

Here, $\zeta_t$ represents the punishment on extra emissions based on the plan, which is the difference between the current emissions $\theta_t x_t$and an emission limit $\varepsilon_t x_{t-1}$ , based on the carbon emissions of the last period.

The cost of the carbon emission plan is a regular daily regulation cost. However, firms have a proportion of production plans that are spontaneously applied. Such a production is more intensive than a normal plan in a short period of time and is usually applied when the overall production plan is overloaded. We define this part of production as *g(x)*. Accordingly, they have a probability $0 \leq P_1 \leq 1$ to face a strict regulation period when they will be punished by $\zeta_t \theta_t g(x)$ if they have high pollution during that period. Such a strict regulation is normally presented by Central MEE Inspection teams. They also have the opportunity to benefit from polluting, with a bonus of $\mu_t \theta_t g(x)$ when regulation is absent, with a probability $0 \leq P_2 \leq 1$ and $\mu_t > 0$. For example, firms can turn off environmental protection cost during the period. Given all the costs, the profit function of each firm is given by:

$$\pi = P(x_t) - v(x_t, h_t) - \zeta_t(\theta_t x_t - \varepsilon_t x_{t-1}) - P_1 \zeta_t \theta_t g(x) + P_2 \mu_t \theta_t g(x) \tag{2}$$

The local government is responsible for daily regulation and the well-being of the population. They also care about the punishment by the central government which may influence their promotions. Their utility function is based on the weighted sum of consumers' utility and firms' utility, including punishments during strict regulation periods when the central government penalizes them for high pollution during inspections. The government's utility function is given by:

$$\begin{aligned}\Omega = \omega(x) - \theta(H)(X) + P(x_t) - v(x_t, h_t) - \zeta_t(\theta_t x_t - \varepsilon_t x_{t-1}) - P_1 \zeta_t \theta_t g(x) \\ + P_2 \mu_t \theta_t g(x) + \alpha(\zeta_t(\theta_t x_t - \varepsilon_t x_{t-1}) - P_1 \kappa_t \theta_t g(x))\end{aligned} \tag{3}$$

This utility function incorporates weights α for governments' own welfare including the fine income on firms for extra emission and punishment $P_1 \kappa_t \theta_t g(x)$ from the central government. Here, $\kappa_t$represents the magnitude of the central government's punishment.

To simplify, we use $g(x) = \beta x_t^2$ . Based on equation (2), we can derive the optimal production value using the first-order condition on $x_t$:

$$x_t = \frac{P - v_{x_t} - \zeta_t \theta_t}{2\beta\theta_t(\zeta_t P_1 - \mu_t P_2)} \tag{4}$$

From equation (4), we find the factors influencing firms' decisions if we simplify the cost function by$v_{x_t} = v$: $\frac{\partial x_t}{\partial \zeta_t} \leq 0, \frac{\partial x_t}{\partial P_1} \leq 0, \frac{\partial x_t}{\partial P_2} \geq 0$. In other words, higher punishment for carbon emissions reduces firms' production and emissions. A higher probability of strict regulation also reduces production, while a higher probability of absent regulation increases production and emissions.

For the government, we can derive their optimal regulation method based on equation (3):

$$(\alpha-1)(\theta_t x_t-\varepsilon_t\theta_{t-1}x_{t-1})=P_1\theta_t x_t^2 \tag{5}$$

This equation indicates that the current method poses a risk for local government officials. Successfully achieving carbon emission reduction plans is beneficial, but this gain can be offset by firms over emission during inspections, which are caught and punished by the central government.

## *4.2 Firms and the Carbon ETS Market*

However, the game has changed with the Carbon ETS market. For firms, participation in the Carbon ETS means not only transactions in the carbon market but also a comprehensive daily emission monitoring system. Therefore, the profit function of each firm is given by:

$$\begin{aligned}\pi_i=P(x_t)-v(x_t,h_t)-\zeta_t\big(1-\epsilon_t(\delta_t)\big)(\theta_t x_t-\varepsilon_t x_{t-1})\\ -\epsilon_t(\delta_t)\lambda_t(\theta_t x_t-\varepsilon_t x_{t-1})-P_1\zeta_t\theta_t g(x,\delta)+P_2\mu_t\theta_t g(x,\delta)\end{aligned} \tag{6}$$

Where $\lambda_t$ represents the stochastic market price of carbon in the local market, which firms must pay for excess emissions $\theta_t x_t-\varepsilon_t x_{t-1}$ by buying carbon. This formation of the carbon market is consistent with the current method of determining carbon allowance in China. $\delta_t$ is the level of carbon ETS development. $\epsilon_t(\delta_t)$ is the probability that a firm is subject to the carbon market. In a more developed market, firms have more opportunities to participate which means $\frac{\partial\epsilon}{\partial\delta}\geq 0$. For firms, spontaneous production is a function of overall production and carbon ETS development. $\frac{\partial g}{\partial\delta}\leq 0$ because a more developed carbon market with better daily monitoring reduces firms' willingness to evade pollution silently. $\xi_t$ is the probability that the central government will penalize the local government for pollution during inspections. Given that the Carbon ETS was introduced by MME (responsible for inspections), inspection teams consider market development as an alternative to emission regulation only when players adhere to the market's rules rather than the government's punishments. Therefore, $\xi_t(\delta_t)$ is lower when the development level $\delta$ is higher, implying better local Carbon ETS market development will be welcomed by inspection teams. Additionally, $\rho_t(\delta_t)$ is the probability for a firm to evade undetected pollution. $\rho_t(\delta_t)$ is lower when $\delta$ is higher, indicating that a more developed market entails more firms being monitored and regulated by the local Carbon ETS. Therefore, firms have difficulty engaging in silent pollution in situation 2.

For governments, the Pilot Carbon ETS market is promoted by local government as an important political achievement, resulting in political competition among leading regions. Since the united Carbon ETS for the entire country is the eventual goal of the pilot scheme, the winner of the local pilot Carbon ETS market development has the opportunity to become a leader in the national Carbon ETS. The government's utility function is recalibrated as:

$$\begin{aligned}\Omega=\omega(x)-\theta(H)(X)+P(x_t)-v(x_t,h_t)-\zeta_t\big(1-\epsilon_t(\delta_t)\big)(\theta_t x_t-\varepsilon_t x_{t-1})\\ -\epsilon_t(\delta_t)\lambda_t(\theta_t x_t-\varepsilon_t x_{t-1})-P_1\zeta_t\theta_t g(x,\delta)+P_2\mu_t\theta_t g(x,\delta)\\ +\alpha(\zeta_t\big(1-\epsilon_t(\delta_t)\big)(\theta_t x_t-\varepsilon_t x_{t-1})-P_1\kappa_t\theta_t g(x,\delta)+S_t(\delta_t))\end{aligned} \tag{7}$$

Where $S_t(\delta_t)$represents the net benefits of a more developed carbon market, including political power, industrial synergy, and economic growth, excluding the cost of market development. To simplify, we use $g(x) = \beta(1 - \epsilon_t)x_t^2$ .Therefore, we can update equation (4) as follows:

$$x_t = \frac{P - v_{x_t} - \lambda_t \epsilon_t \theta_t - \zeta_t(1 - \epsilon_t)\theta_t}{2\beta\theta_t(1 - \epsilon_t)(\zeta_t P_1 - \mu_t P_2)} \tag{8}$$

As $0 < \zeta_t < 1; 0 < \mu_t < 1$ , changes of $P_1, P_2$result in negligible changes in $x_t$ if $\delta_t$ is high enough and $\zeta_t \rightarrow 0, \mu_t \rightarrow 0$. For the government, we can derive the first-order condition on the regulation method $\zeta^*$ based on equation (7), yielding:

$$P_1\beta\theta_t x_t^2 = (1 - \alpha)\big(1 - \epsilon_t(\delta_t)\big)(\theta_t x_t - \varepsilon_t x_{t-1}) \tag{9}$$

This indicates that the expected penalties on firms' excess emissions during inspections are reduced by $\epsilon_t(\delta_t)$ compared to an economy without a carbon market. Now, the local government has an additional essential tool for emission reduction — carbon market development. Deriving the first-order condition on (7) and (6), we obtain the condition of equilibrium market development:

|

$$S_\delta = -P_1\kappa_t\epsilon_\delta\theta_t x_t^2 + \epsilon_\delta\zeta_t(\theta_t x_t - \varepsilon_t x_{t-1}) \tag{10}$$

Since $\epsilon_\delta \leq 0, S_\delta \geq 0$, the above equation (10) implies that the optimal market development strategy for the government is when the government's benefit from an improved carbon market is equivalent to the benefit change for firms.

When will carbon ETS contribute to improvement in carbon emission reduction and political uncertainty amelioration? For the resolution of market failure, we expect carbon ETS to induce lower emission and emission intensity. According to (4) and (8). To simplify the model, we use $\xi_t = \rho_t = (1 - \epsilon_t)$, which aligns with the assumption that a better carbon market reduces the penalties for inspections and the bonuses for silent emissions. So we need:

$$x_c < x_{nc} \tag{11}$$

$$\theta_c < \theta_{nc} \tag{12}$$

To fix the government failure, carbon ETS should have a moderate effect on political uncertainty effect. Comparing the different $\frac{\partial x_t}{\partial P}$ for equation (4) and (8) helps explain the change in the political uncertainty effect caused by the carbon market. Consequently, we get:

$$\frac{\partial x_{t,nc}}{\partial P_{1,nc}} < \frac{\partial x_{t,c}}{\partial P_{1,c}} \tag{13}$$

$$\frac{\partial x_{t,nc}}{\partial P_{2,nc}} > \frac{\partial x_{t,c}}{\partial P_{2,c}} \tag{14}$$

With (11),(12),(13), (14), we get the efficient carbon market condition:

$$P - v_{x_t} - \lambda_t\theta_t < 0 \tag{15}$$

As existing literature has scrutinized the current low carbon price, (15) is an intuitive condition when the carbon price is high enough for firms to change their mind about pollution. Firms will get free allowance according to the carbon emission reduction plan. They will change their production plan if their marginal profit is lower than the current carbon price which means if they have extra emissions their total profit decline. Accordingly, Therefore, a high carbon price changes the game. As the cost of emissions becomes expensive, firms release less carbon and retreat from polluting industries.

This model implies that to reduce the political uncertainty effect, a developed market should maintain a high carbon price, making the cost of purchasing every unit of carbon they produce unaffordable. An efficient carbon market smoothing their emission by neglecting the special period with or without regulations. Conclusively, the adequate carbon price will not only achieve the goal of carbon emission reduction but also reduce the political uncertainty effect.

## 5. Data and Methods

### *5.1 Data sources and sample (China's carbon emission trading market)*

The dependent variable of this study is air quality. It is measured by a wide range of indicators in the literature, such as air quality index, PM2.5, CO2, etc (Chen and Whalley, 2012; Davis, 2008; Fu and Gu, 2017; Viard and Fu, 2015; Zhang et al., 2017; Zhong et al., 2017).

In 2012, China updated its air quality index (AQI) to include six pollutants, namely SO2, NO2, PM10, PM2.5, O3, and CO, in order to better evaluate the air pollution level according to Technical Regulation on Ambient Air Quality Index. This new AQI is a more comprehensive indicator than the previous air pollution index (API) as it incorporates three additional pollutants (PM2.5, O3, and CO) and reflects a higher value when the air pollution is more severe(Greenstone et al., 2022). Consequently, recent studies have adopted AQI as the core indicator of air pollution levels (Li et al., 2021; Xue et al., 2021; Wang et al., 2021). Therefore, we focus on daily AQI in our research and also cover alternative measures in the robustness check.

Besides, weather conditions play a crucial role in determining the level of air pollution and emission. For example, precipitation and wind can reduce the concentration of pollutants such as PM10 (Rost et al., 2009; Jones et al., 2010), while humidity, temperature, and sunshine are related to other pollutants such as ozone (Fu and Gu, 2017). Therefore, we included the main weather condition variables as controls in our analysis, such as time of sunshine, average wind speed, 24-hour precipitation, average humidity, and average temperature.

The sample periods started from October 28th 2013, to December 31st 2019, covering 270 cities from 31 provinces in China. The variables are the AQI (higher index implies lower air quality), pollutants' density (μg/m3), time of sunshine (0.1 hours), precipitation in 24 hours (0.1 mm), average wind speed(0.1m/s), average humidity(1%), average temperature(0.1℃), turnover of municipal leaders(1 for days in the week before the announcement of turnover), holiday dummy, inspection(1 during inspection). Air quality data are collected from China National Environment Monitoring Center. Weather data is collected from National Meteorological Information Center. Turnover, inspection and holiday data are collected from official websites manually.

### *5.2 Unannounced inspections*

Travelling inspection represents a highly efficient and well-known approach for the Ministry of Ecology and Environment (MEE) to fulfil its mission in daily work. In fact, since 2012, the inspection teams have played a vital role in the anti-corruption campaign under the leadership of Chairman Xi. Typically, these inspection teams are led by powerful government officials who previously held provincial leadership roles, and they conduct unannounced visits to provinces or state-owned enterprises (SOEs) to assess compliance with regulations and rules. As addressing climate change is a top priority for MEE, carbon emissions have always been a critical area of inspection.

Local government takes the visits by inspection teams exceptionally seriously due to the political status of the team leader and the severe consequences that could result from any wrongdoing detected. According to the MEE website, the travelling inspection teams report their arrival in the provincial capital on the website and typically spend one month in the province. Table 2 shows the schedule of MEE inspections from 2016 to 2019, covering all 31 regions in our sample. Most provinces and cities experienced two inspections, while several areas, including Tibet, Xinjiang, and Tianjin, only experienced one inspection. To identify the impact of travelling inspections on the environment, we constructed dummies for travelling inspections based on the information provided on the MEE website. Specifically, the dummy variable takes a value of 1 when the inspection team is currently inspecting the province or city, which is consistent with existing literature(Zheng and Na 2020).

**Table 1: Unannounced inspections**

| Date | Province | Date | Province | Date | Province |
|---|---|---|---|---|---|
| 2016/1/4 | Hebei | 2017/4/27 | Anhui | 2018/6/6 | Jiangsu |
| 2016/7/12 | Ningxia | 2017/4/28 | Tianjin | 2018/6/6 | Yunnan |
| 2016/7/14 | Guangxi | 2017/4/29 | Shanxi | 2018/6/7 | Guangxi |
| 2016/7/14 | Inner Mongolia | 2017/7/19 | Heilongjiang | 2018/10/30 | Hunan |
| 2016/7/14 | Jiangxi | 2017/8/7 | Sichuan | 2018/10/31 | Anhui |
| 2016/7/15 | Yunnan | 2017/8/8 | Qinghai | 2018/10/31 | Hubei |
| 2016/7/16 | Henan | 2017/8/10 | Shandong | 2018/11/1 | Shandong |
| 2016/11/24 | Chongqing | 2017/8/11 | Hainan | 2018/11/3 | Shaanxi |
| 2016/11/26 | Hubei | 2017/8/11 | Jilin | 2018/11/3 | Sichuan |
| 2016/11/28 | Guangdong | 2017/8/11 | Xinjiang | 2018/11/4 | Guizhou |
| 2016/11/28 | Shaanxi | 2017/8/12 | Zhejiang | 2018/11/4 | Liaoning |
| 2016/11/28 | Shanghai | 2017/8/15 | Tibet | 2018/11/5 | Jilin |
| 2016/11/29 | Beijing | 2018/5/30 | Heilongjiang | 2019/7/8 | Beijing |
| 2016/11/30 | Gansu | 2018/5/31 | Hebei | 2019/7/9 | Shanghai |
| 2017/4/24 | Fujian | 2018/6/1 | Henan | 2019/7/12 | Chongqing |
| 2017/4/25 | Hunan | 2018/6/2 | Ningxia | 2019/7/12 | Gansu |
| 2017/4/25 | Liaoning | 2018/6/3 | Jiangxi | 2019/7/14 | Hainan |
| 2017/4/26 | Guizhou | 2018/6/5 | Guangdong | 2019/7/14 | Qinghai |
|  |  | 2018/6/6 | Inner Mongolia | 2019/7/15 | Fujian |

### *5.3 Turnovers of senior local government officials*

We focus our attention on high-ranking officials in a given city, specifically the mayor and head secretary. We manually collected information on their turnover from official websites, such as ce.cn and local government websites. While some turnovers may be unpredictable prior to their announcement, most turnovers have information leakage beforehand. Consequently, political uncertainty in the short period before the announcement of turnover is extremely high for firms and other agents in the city. To maximize the turnover effect during this short period, we exclude turnovers that occurred 14 days before the next turnover shock. These methods also help us to keep the consistency of data in event study research and the RD model in section 5.5. Our sample consists of 1282 turnovers for 270 cities during the sampling period, while one city had no turnovers during the sampling period. Table 3 shows the distribution of turnovers among different regions. Most regions had over 40 turnovers during the period, while minority autonomous regions like Tibet, Guangxi, and Xinjiang had fewer turnovers. To capture the effect of officials' turnover, we constructed dummies that take a value of 1 for days within one week before the turnover and 0 for other dates. We also applied alternative windows as a robustness check in section 5.3.

**Table 2: City-level leader turnovers (2013 – 2019)**

| Province | Turnovers | Province | Turnovers |
|---|---|---|---|
| Anhui | 44 | Jiangsu | 44 |
| Beijing | 4 | Jiangxi | 43 |
| Chongqing | 5 | Jilin | 59 |
| Fujian | 30 | Liaoning | 88 |
| Gansu | 41 | Ningxia | 15 |
| Guangdong | 100 | Qinghai | 16 |
| Guangxi | 36 | Shaanxi | 30 |
| Guizhou | 43 | Shandong | 65 |
| Hainan | 4 | Shanghai | 2 |
| Hebei | 42 | Shanxi | 58 |
| Heilongjiang | 73 | Sichuan | 56 |
| Henan | 61 | Tianjin | 3 |
| Hubei | 54 | Tibet | 16 |
| Hunan | 57 | Xinjiang | 35 |
| Inner Mongolia | 51 | Yunnan | 51 |
| | | Zhejiang | 56 |

### *5.4 Other control variables (i.e., city, month and holiday fixed effects).*

To account for the holiday effect which caused the possible traffic condition change(Fu and Gu 2017), we introduce a holiday dummy variable that takes a value of 1 on official holidays, such as New Year, Spring Festival, Tomb-Sweeping Day, Labor Day, Dragon Boat Festival, Mid-Autumn Festival, and National Day. By incorporating this variable, we aim to account for any variations in traffic patterns that may be attributed to the occurrence of holidays.

**Table 3. Summary Statistics**

| Variable | Obs | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| AQI(Air Quality Index) | 511,772 | 74.22 | 47.50 | 0 | 500 |
| PM2.5(μg/m3) | 511,772 | 44.29 | 39.57 | 0 | 1787 |
| PM10(μg/m3) | 511,772 | 79.89 | 77.54 | 0 | 8818 |
| SO2(μg/m3) | 511,772 | 19.32 | 23.12 | 0 | 800 |
| NO2(μg/m3) | 511,772 | 29.10 | 17.37 | 0 | 471 |
| O3(μg/m3) | 511,772 | 58.77 | 29.60 | 0 | 435 |
| CO(μg/m3) | 511,772 | 0.98 | 0.57 | 0 | 25.69 |
| Sunshine(0.1 hour) | 511,772 | 56.45 | 41.57 | 0 | 155 |
| Precipitation(0.1mm) | 511,772 | 27.79 | 96.90 | 0 | 4552 |
| Wind Speed(0.1m/s) | 511,772 | 21.72 | 12.24 | 0 | 205 |
| Humidity(1%) | 511,772 | 67.38 | 19.05 | 3 | 100 |
| Temperature(0.1°C) | 511,772 | 139.55 | 112.33 | -388 | 423 |
| Turnover | 511,772 | 0.02 | 0.12 | 0 | 1 |
| Holiday | 511,772 | 0.07 | 0.25 | 0 | 1 |
| Inspection | 511,772 | 0.03 | 0.16 | 0 | 1 |

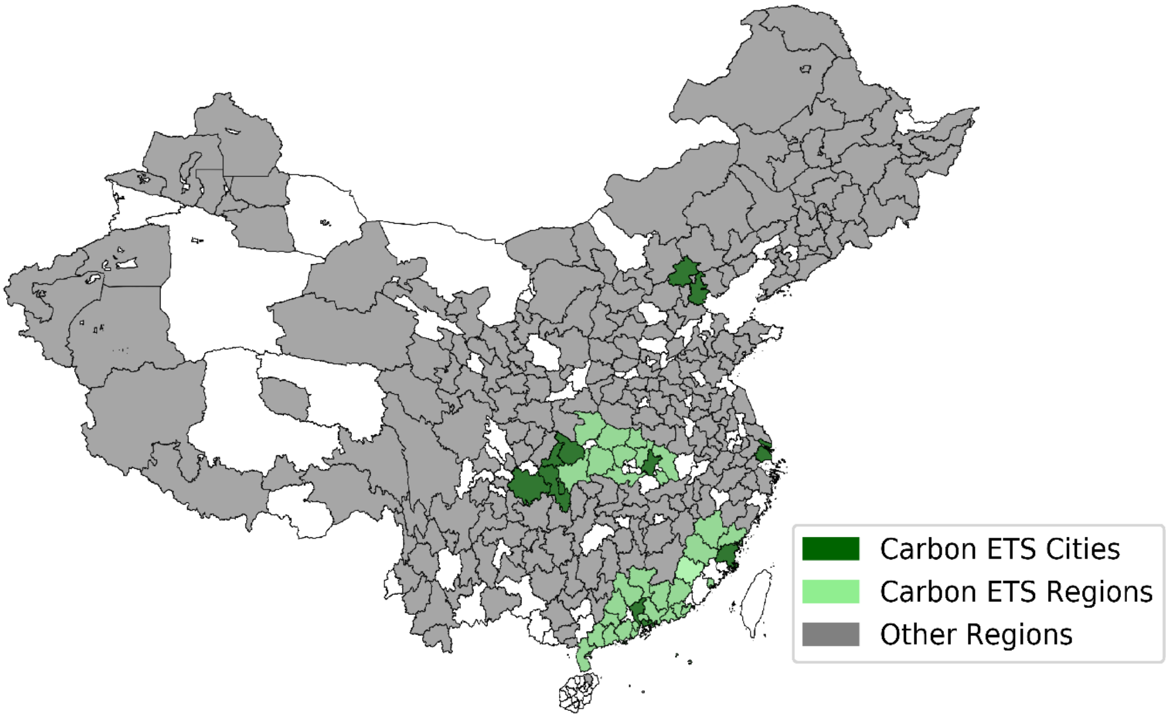

**Figure 1. Sample Cities, Pilot Carbon ETS Cities and Pilot Carbon ETS Regions**
The Figure shows the distribution of cities in our sample. Cities covered by dark green are cities with Pilot Carbon ETS. Regions coloured by light green are cities covered by provincial Carbon ETS. Gray regions are other cities in our sample.

### *5.5 Empirical model and estimation techniques*

Our main model based on panel data and city level fix effects.

$$LnAQI_{it} = \alpha_i + \gamma_t + \beta_1 Turnover_{it} + \beta_2 Inspection_{it} + \theta Holiday_t + \delta W_{it} + \varepsilon_{it} \quad (1)$$

The benchmark model examines the relationship between air quality and political uncertainty and central travelling inspection. The dependent variable, $LnAQI_{it}$, is the natural logarithm of the Air Quality Index (AQI) in the city i on day t. We also consider other air pollutant measures, including PM2.5, PM10, SO2, NO2, CO, and O3, in the logarithmic form. The model includes city and monthly fixed effects, denoted by $\alpha_i$ and $\gamma_t$, respectively, to control for unobserved, time-invariant city-specific characteristics and time effects within a month. $Turnover_{it}$ is 1 for days in a week before the turnover of senior officials in the city i. $\beta_1$ is the coefficient describing the effect of political uncertainty on local air quality. $Inspection_{it}$ is 1 if the central travelling inspection is inspecting the province of the city i. $\beta_2$ describe the inspection effect on air quality. $Holiday_t$ is 1 for official holidays. And $W_{it}$ includes weather controls, namely the level of sunshine, wind speed, precipitation, humidity and temperature for the city I on day t. $\varepsilon_{it}$ is the error term.

To further test for the structural break caused by the turnover, we also adopt a regression discontinuity(RD) design which identifies potential breaks in two parametric series before and after turnovers(Greenstone et al. 2022).The RD model can be written as follows:

$$\begin{aligned} LnAQI_{it} = {} & \alpha_i + \gamma_t + \beta_1 AfterTurnover_{it} + \beta_2 f(t - TurnDate_{it}) \\ & + \beta_3 AfterTurnover_{it} * f(t - TurnDate_{it}) + \beta_4 Inspection_{it} \\ & + \theta Holiday_t + \delta W_{it} + \varepsilon_{it} \end{aligned} \quad (2)$$

where $LnAQI_{it}$ also indicates the log form pollution levels reported by in the city i on day t. $AfterTurnover_{it}$ is an indicator variable that equals one if city i at time t is in 7 days after a local leader's turnover. $t - TurnDate_{it}$ represents the number of days from the turnover and is the running variable. We include a "control function," $f(t - TurnDate_{it})$, and allow it to differ pre and post turnovers. We also controls similar variables as equation 1 including inspection, holiday, weather indicators and fixed effects.

The parameter of interest, $\beta 1$, estimates whether there is a discontinuity in air pollution levels immediately post the turnover, after flexible adjustment for the days before/after automation and the covariates. We estimate the RD by firstly get residual in regression which is similar to equation 1 but without turnover indicators and then conduct RD analysis on the residual. This procedure provides a consistent estimate of the same RD parameter of interest (Lee and Lemieux 2010).

## 6. Empirical Findings and Discussions

### *6.1 Test of Hypothesis 1 (effect of unannounced turnovers and inspections)*

Table 2 presents the empirical findings of our first hypothesis, using the Difference-in-Differences (DID) model and panel data. We examine seven different measures of air pollution in this table, controlling for city fixed effects, monthly fixed effects, holiday effects, and weather conditions. The first column of Table 2 presents our main result, revealing that both turnovers and inspections significantly affect local air quality, albeit in opposite directions.

Specifically, during the turnover window, the air quality deteriorates by 2.2% with a 1% level of significance. In contrast, during the inspection period, air quality improves by 5%, which aligns with our hypothesis and prior research. Importantly, turnover effects remain significant in Columns 2, 3, and 5, while inspection effects remain significant across all seven columns. Furthermore, turnover has a higher impact on PM10 and PM2.5, exceeding 2.5%, while it does not significantly influence the concentration of SO2, CO, and O3. In contrast, inspection has the highest impact on SO2, with a 9.9% decrease.

Table 2 also provides additional insights by revealing that wind speed, precipitation, and humidity are negatively associated with air pollutants such as PM2.5,PM10 and SO2, consistent with existing literature(Fu and Gu 2017;Deryugina et al., 2019; Brodeur et al.2021).

On RD estimate, we start by visualizing the patterns in the data. In Figure 1(A), we plot the raw daily reported AQI concentration data. Figure 1(B) plots the residualized concentrations after adjustment for all controls in equation 1 without turnover. In both panels, we observe a striking decrease in reported AQI immediately after turnovers.

We then present RD estimates from equation (2) in Table 1(A). To comply with the baseline DID model ,the bandwidths are 7 days in all columns. Columns (1) to (3) report the results with linear polynomial function and columns (4) to (6) report the results with quadratic polynomial functions. We use three different kernel weighting strategies in Table 1 including Triangle, epanechnikov, and uniform. The RD estimate have similar results in different columns. Turnovers result in a 2.5% to 3.2% air quality deterioration in table 1 which is closed to the DID estimate in table 1. Therefore, the date of turnover announcement induce a clear discontinuity in air quality. When political uncertainty suddenly settled with the announcement, polluters stop pollution as they believe the regular regulation and monitoring system is back.

**Table 4. Political Uncertainty and Local Air Quality**

The table reports the results of DID regressing log air quality indicators against a dummy for political uncertainty(Turnover) and a series of controls. Turnover is 1 for days in the week before local leaders' turnover. Standard errors are clustered at the city level. Robust t-statistics are in parenthesis. ***, **, and * correspond to statistical significance at 1%,5% and 10% levels respectively.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | log(AQI) | log(PM2.5) | log(PM10) | log(SO2) | log(NO2) | log(CO) | log(O3) |
| Turnover | 0.0220*** | 0.0241** | 0.0250*** | 0.0154 | 0.0155** | -0.0057 | -0.0099 |
| | (2.94) | (2.31) | (2.64) | (1.28) | (2.19) | (-0.76) | (-1.07) |
| Inspection | -0.0504*** | -0.0781*** | -0.0707*** | -0.0993*** | -0.0319*** | -0.0221** | -0.0397*** |
| | (-6.69) | (-7.41) | (-7.12) | (-6.02) | (-3.04) | (-2.32) | (-3.27) |
| Sunshine | -0.0002* | -0.0007*** | -0.0005*** | 0.0005*** | 0.0001 | -0.0001* | 0.0020*** |
| | (-1.86) | (-5.13) | (-3.85) | (4.27) | (0.62) | (-1.70) | (18.66) |
| Precipitation | -0.0006*** | -0.0010*** | -0.0009*** | -0.0004*** | -0.0002*** | -0.0001*** | -0.0001*** |
| | (-21.65) | (-25.89) | (-23.93) | (-12.70) | (-7.60) | (-7.64) | (-5.71) |
| Wind Speed | -0.0057*** | -0.0109*** | -0.0081*** | -0.0112*** | -0.0161*** | -0.0070*** | 0.0052*** |
| | (-12.37) | (-17.66) | (-12.78) | (-17.97) | (-20.72) | (-19.15) | (11.47) |
| Humidity | -0.0024*** | 0.0010 | -0.0060*** | -0.0084*** | -0.0020*** | 0.0033*** | -0.0058*** |
| | (-5.30) | (1.53) | (-10.87) | (-16.76) | (-5.75) | (11.56) | (-10.64) |
| Temperature | 0.0015*** | 0.0017*** | 0.0018*** | -0.0017*** | 0.0006*** | 0.0004*** | 0.0017*** |
| | (12.76) | (10.25) | (12.40) | (-10.12) | (5.79) | (4.02) | (9.10) |
| City FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Holiday | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 511,760 | 511,704 | 511,602 | 511,725 | 511,710 | 511,690 | 511,689 |
| R2 | 0.4891 | 0.5228 | 0.5363 | 0.6203 | 0.6484 | 0.5285 | 0.5085 |

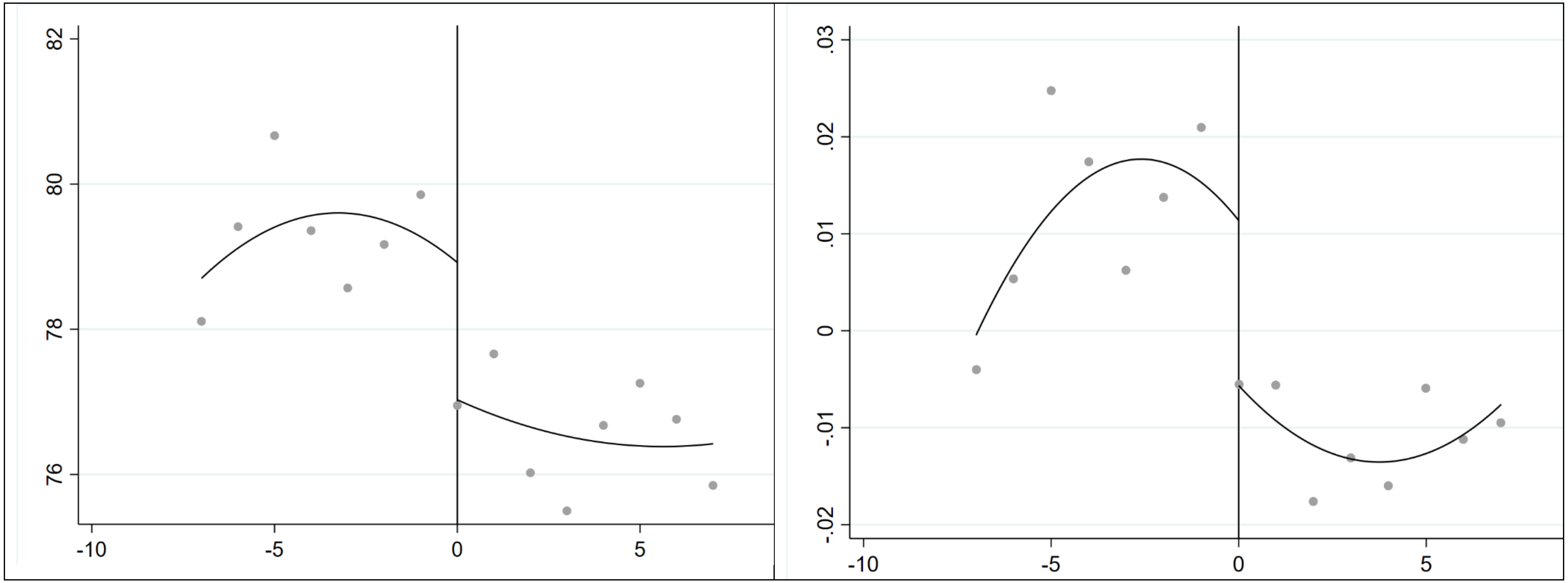

**Figure 2. RD Plots for AQI and Residual of AQI Estimate**
The Figure shows the decrease of pollution immediately after local leaders' turnovers. Bandwidth is 7 in both Panel (A) and (B). Panel (A) uses the raw AQI value and Panel (B) uses the residual of equation 1 without turnovers.

**Table 5. RDD Estimates of Air Pollution After Turnovers**

The table reports the results of non-parametric RD estimate of residualized log air quality indicators against turnover. The bandwidths are 7 days in all columns. Columns (1) to (3) report the results with linear polynomial function and columns (4) to (6) report the results with quadratic polynomial functions. We use three different kernel weighting strategies in Table 1 including Triangle, epanechnikov and uniform. Standard errors are clustered at the city level. Robust t-statistics are in parenthesis. ***, **, and * correspond to statistical significance at 1%,5% and 10% levels respectively.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| AfterTurnover | -0.025* | -0.025* | -0.032** | -0.025* | -0.025* | -0.032** |
| | (-1.84) | (-1.85) | (-2.56) | (-1.84) | (-1.85) | (-2.56) |
| Local Polynomial | Linear | Linear | Linear | Quadratic | Quadratic | Quadratic |
| Kernel | Tri. | Epa. | Uni. | Tri. | Epa. | Uni. |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| City FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Holiday | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 17,096 | 17,096 | 17,096 | 17,096 | 17,096 | 17,096 |

### *6.2 Test of Hypothesis 2 (the moderating effect of ETS)*

Chinese cities vary dramatically in many respects. Therefore, to further explore the turnover effect and inspection effect based on the heterogeneity among cities, we decompose the city sample according to our Hypothesis 2. By deriving the effect in different groups, we show how cities react to turnover and inspections differently. Table 6 shows the difference and mechanism of the effect.

Column 1 uses the subsample of regions covered by provincial carbon ETS. There are seven regional carbon ETS supported by the Development and Reform Commission since 2013: Beijing, Shanghai, Shenzhen, Guangdong, Hubei, Chongqing and Tianjin. Moreover, on December 22, 2016, Fujian opened a new provincial carbon ETS, the only trading carbon allowance besides the above 7 ETS. These eight carbon ETS mainly focused on firms in the province and were the core of carbon emission transactions before 2021, when the national carbon ETS opened. With the systematic regulation and management of carbon emissions, firms and governments in those provinces and cities were operating the game of cat and mouse differently compared to regions without carbon ETS. Therefore, we found that the turnover and inspection effect patterns are much different in column 1. The coefficient of turnover is insignificant, while the coefficient of inspection is significantly positive. This result is entirely different from the pattern in column 2, using the subsample of regions without carbon ETS. Such a divergence is likely the result of carbon ETS, which changes the behaviour of firms.

Moreover, we use an interaction term to derive the influence of carbon ETS on the turnover and inspection effect. In column 3, we use a dummy for carbon ETS and its interaction term with turnover and inspection dummies. *Carbon ETS (covered)* is 1 for cities that start to be covered by a provincial carbon ETS. Since all eight carbon ETS opened on different dates, we chose the market opening date as the start of the dummy for carbon ETS. The turnover and inspection effects become significant with the carbon ETS and interaction terms. Air quality deteriorates by 2.94% during the turnover window and improves by 5.9% during inspections. The magnitude of the effect is larger than that in Table 2. More importantly, the coefficient of the interaction term of *Carbon ETS (covered) * Turnover* is significantly negative, and that for *Carbon ETS (covered) * Inspection* is significantly positive. Establishing a carbon ETS seems to form self-regulation that limits the emission during the turnover period by 5.04% and induces the emission during inspections by 5.51%. Therefore, the ETS effect hedges abnormal air quality turbulence during turnovers and inspections.

Establishing carbon emissions trading schemes (ETS) in provincial capitals is more likely to impact cities that are already their respective provinces' economic and political centres. To test the effect of carbon ETS, we analyze subsamples consisting only of cities with established carbon ETS in column 4. The results indicate that turnover and inspection effects are insignificant, contrasting those obtained from other cities in column 5. To further assess the influence of carbon ETS, we utilize a set of interaction terms similar to column 3 in column 6. Here, the coefficient of *Carbon ETS(location)* remains insignificant, but the coefficient of *Carbon ETS(Location)*Turnover* is -9.34%, higher than the effect observed in column 3. This implies that the self-regulation of firms in capital cities is more significant than firms in other cities. Conversely, the coefficient of *Carbon ETS(Location)*Inspection* is insignificant.

## Table 6. Political Uncertainty, air pollution and Carbon ETS

The table reports the results of DID regressing log air quality indicators against a dummy for political uncertainty(Turnover), an interaction term between Turnover and Carbon ETS. Turnover is 1 for days in the week before local leaders' turnover. Carbon ETS(Covered) is one if the city has been covered by one of the eight provincial Carbon ETS. Carbon ETS(location) is one if the city has a provincial Carbon ETS. Column 1 uses the subsample of only regions finally covered by eight provincial carbon ETS. Column 4 uses the subsample of cities with Carbon ETS finally. Standard errors are clustered at the city level. Robust t-statistics are in parenthesis. ***, **, and * correspond to statistical significance at 1%,5% and 10% levels respectively.

| | (1) Regions Covered by Carbon ETS | (2) Other | (3) All | (4) Cities with Carbon ETS | (5) Other | (6) All |
|---|---|---|---|---|---|---|
| Turnover | -0.0030 | 0.0248*** | 0.0294*** | -0.0206 | 0.0237*** | 0.0246*** |
| | (-0.19) | (3.06) | (3.60) | (-0.88) | (3.12) | (3.23) |
| Inspection | 0.03** | -0.0562*** | -0.0590*** | -0.01 | -0.0510*** | -0.0518*** |
| | (2.05) | (-7.04) | (-7.37) | (-0.20) | (-6.68) | (-6.79) |
| Sunshine | 0.0003 | -0.0003*** | -0.0002* | 0.0009 | -0.0002** | -0.0002* |
| | (1.59) | (-3.48) | (-1.88) | (1.88) | (-2.29) | (-1.87) |
| Precipitation | -0.0004*** | -0.0007*** | -0.0006*** | -0.0005*** | -0.0006*** | -0.0006*** |
| | (-6.51) | (-21.29) | (-21.68) | (-3.59) | (-21.33) | (-21.65) |
| Wind Speed | -0.0116*** | -0.0050*** | -0.0057*** | -0.0123*** | -0.0056*** | -0.0057*** |
| | (-11.74) | (-10.85) | (-12.37) | (-8.26) | (-11.99) | (-12.37) |
| Humidity | -0.0058*** | -0.0019*** | -0.0024*** | 0.0022 | -0.0026*** | -0.0024*** |
| | (-2.92) | (-4.12) | (-5.30) | (0.47) | (-5.83) | (-5.30) |
| Temperature | 0.0016*** | 0.0016*** | 0.0015*** | 0.0022*** | 0.0015*** | 0.0015*** |
| | (6.09) | (12.26) | (12.78) | (4.64) | (12.56) | (12.76) |
| Carbon ETS(Covered) | | | 0.0020 | | | |
| | | | (0.10) | | | |
| Carbon ETS(Covered)*Turnover | | | -0.0504** | | | |
| | | | (-2.20) | | | |
| Carbon ETS(Covered)*Inspection | | | 0.0551*** | | | |
| | | | (3.56) | | | |
| Carbon ETS(location) | | | | | | -0.0181 |
| | | | | | | (-0.44) |
| Carbon ETS(Location)*Turnover | | | | | | -0.0934*** |
| | | | | | | (-2.92) |
| Carbon ETS(Location)*Inspection | | | | | | 0.0460 |
| | | | | | | (1.09) |
| City FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Holiday | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 78,817 | 432,943 | 511,760 | 16,794 | 494,966 | 511,760 |
| R2 | 0.4849 | 0.491 | 0.4892 | 0.4367 | 0.4926 | 0.4891 |

While Table 6 investigates the impact of carbon ETS on turnover and inspection effects in the sample, the differences between cities with and without carbon ETS may result from endogeneity. Specifically, first-tier cities such as Beijing, Shanghai, Shenzhen, and Guangzhou possess advanced economies and political status. To exclude any unobserved factors influencing the sample, we replicate the models in Table 6, columns 3 and 6 on subsamples of these cities.

Table 7 demonstrates the impact of the establishment of the carbon emissions trading scheme (ETS) on cities with advanced institutions. Given that all inspections occurred after the establishment of carbon ETS, there is no interaction term between carbon ETS and inspection in Table 7. In column 1, we utilize the subsample of cities covered by carbon ETS. The results indicate that the turnover effect is significant for cities covered by carbon ETS, with a coefficient of 10.25%, considerably higher than that observed in Table 4, column 3. However, this substantial effect is tempered by the interaction term, which has a coefficient of -11.18% after the ETS establishment. Furthermore, inspection effects for these cities are significantly positive.

In column 2, we analyze subsamples of cities with carbon ETS. Here, the turnover effect reaches 14.61%, even higher than in column 1. Additionally, the interaction term has a more substantial hedge effect, with *Carbon ETS(Location)*Turnover* having a coefficient of 18.2%, much larger than the turnover effect. Conversely, the coefficient for the inspection effect is insignificant and negative.

Table 7 has several noteworthy implications. Firstly, it establishes that even advanced cities experience significant changes in air quality following the establishment of carbon ETS. The magnitude of the turnover effect is particularly notable for the capitals in developed regions, consistent with the Chinese government's distinguished influence on the economy and society. Remarkably, carbon ETS, a comprehensive market-based regulatory system, helps to reduce political uncertainty considerably.

Finally, while air quality in cities with carbon ETS does not experience significant changes during inspections, other regions experience even worse air quality. One possible explanation is that when inspection teams arrive at the capitals, other cities are informed about the inspection but not the schedule. The so-called inspection does not indicate that the traveling inspection team is inspecting every city of the province every day during the inspections. In fact, the team travels around the province to inspect as a traveling inspection team. Therefore, cities, except for capitals, have time to prepare for inspections. While not all cities are covered by inspections, most want to perform well. Therefore, before the arrival of the inspection teams, firms in these cities may accelerate short-term emissions to ensure lower emissions when the teams arrive. Also, they may have over-emission after the inspection to remedy for the “good performance” during inspections. Such behaviour is highly risky for cities without carbon ETS since they face punishment when caught. However, as cities covered by carbon ETS can purchase additional allowances in the market if caught, the only cost is future allowance purchase. As a result, the risky behaviour of these cities leads to increased emissions as not all cities are inspected. We provide further evidence in the next section.

**Table 7. Leading Regions in Carbon ETS and air pollution during Political Uncertainty**

To exclude endogenous factors of different regions, the table reports the results of DID regressing log air quality indicators against a dummy for political uncertainty(Turnover), an interaction term between Turnover and Carbon ETS using subsamples. Turnover is 1 for days in the week before local leaders' turnover. Carbon ETS(Covered) is one if the city has been covered by one of the eight provincial Carbon ETS. Carbon ETS(location) is one if the city has a provincial Carbon ETS. Column 1 uses the subsample of only regions which eight provincial carbon ETS finally covers. Column 2 uses the subsample of cities with Carbon ETS finally. Standard errors are clustered at the city level. Robust t-statistics are in parenthesis. ***, **, and * correspond to statistical significance at 1%,5% and 10% levels respectively.

| | (1) Regions Covered by Carbon ETS | (2) Cities with Carbon ETS |
|---|---|---|
| Turnover | 0.1025*<br>(2.00) | 0.1461***<br>(3.59) |
| Inspection | 0.0345**<br>(2.11) | -0.0106<br>(-0.22) |
| Carbon ETS(Covered) | -0.0240<br>(-1.08) | |
| Carbon ETS(Covered)*Turnover | -0.1118**<br>(-2.12) | |
| Carbon ETS(location) | | 0.0042<br>(0.08) |
| Carbon ETS(Location)*Turnover | | -0.1821***<br>(-4.90) |
| Controls | Yes | Yes |
| City FE | Yes | Yes |
| Month FE | Yes | Yes |
| Holiday | Yes | Yes |
| N | 78,817 | 16,794 |
| R2 | 0.4851 | 0.4368 |

**Table 8. Leading Regions in Carbon ETS and air pollution during Political Uncertainty**

To exclude endogenous factors of different regions, the table reports the results of DID regressing log air quality indicators against a dummy for political uncertainty(Turnover), an interaction term between Turnover and Carbon ETS using subsamples. Turnover is 1 for days in the week before local leaders' turnover. Carbon ETS(Covered) is one if the city has been covered by one of the eight provincial Carbon ETS. Carbon ETS(location) is one if the city has a provincial Carbon ETS. Column 1 uses the subsample of only regions which eight provincial carbon ETS finally covers. Column 2 uses the subsample of cities with Carbon ETS finally. Standard errors are clustered at the city level. Robust t-statistics are in parenthesis. ***, **, and * correspond to statistical significance at 1%,5% and 10% levels respectively.

| | (1) Regions Covered by Carbon ETS | (2) Cities with Carbon ETS |
|---|---|---|
| Turnover | 0.0961** | 0.1772** |
| | (2.40) | (2.01) |
| Inspection | -0.0077 | -0.0296 |
| | (-0.29) | (-0.37) |
| Carbon Price | -0.0028*** | -0.0025** |
| | (-5.57) | (-2.34) |
| Carbon Price*Turnover | -0.0041** | -0.004** |
| | (-2.52) | (-2.43) |
| Carbon Price*Inspection | 0.0031*** | 0.0016 |
| | (2.80) | (1.11) |
| Controls | Yes | Yes |
| City FE | Yes | Yes |
| Month FE | Yes | Yes |
| Holiday | Yes | Yes |
| N | 38,463 | 6,482 |
| R2 | 0.5022 | 0.4616 |

### *6.3 Efficient ETS Condition and ETS Moderate Effect*

Though 6.2 confirm the moderate effect of ETS which helps to reduce the political uncertainty effect on carbon emission, the mechanism of the effect remain unclear. Specially, as early research has mentioned, carbon ETS is not always efficient in carbon emission reduction. Therefore, an inefficient carbon market may not always have further moderate effect on political uncertainty. How could carbon ETS works efficiently? And What is the condition for carbon ETS to moderate political uncertainty?

In section 4, we apply the equation (11), efficient market condition of carbon ETS, which to reach the efficient carbon market situation. Such a condition requires the carbon price is high enough for firms to reduce their pollution. In reality, heterogenous firms have various marginal profit and react to carbon price differently. But as the carbon price gets higher, more firms have to shut down their pollution. Therefore, carbon price should have a positive effect on carbon emission reduction and political uncertainty effect. As for Chinese carbon ETS pilot scheme, provincial ETS aims to firstly cover local firms, local carbon price represents the constraint for local firms. Accordingly, we apply the local carbon price and its interaction term with inspection and turnover in this section to see if higher carbon price reduce carbon emission and political uncertainty effect.

Table 8 represents the effect of carbon price on carbon emission and political uncertainty effect using only regions and cities covered by carbon ETS and periods with carbon trading. Carbon Price is the close price of the core index in the local carbon ETS, in Yuan per ton of carbon emission. In Column 1 , the coefficient of *Carbon Price* and *Carbon Price*Turnover* are significantly negative and coefficient for *Carbon Price*Inspection* is significantly positive. Therefore, for regions covered by carbon ETS, 1 Yuan of Carbon price increase reduce local carbon emission by 0.28%. It also reduce the effect of turnovers by 0.41% and reduce the effect of inspections by 0.31%. Column 2 shows the estimate for cities with carbon ETS. While Carbon price has a similar reduction on carbon emission and turnover effect, it has no significant effect on inspections. It is consistent with the result in Table 7, which indicates that turnovers is highly exogenous for all cities while inspections only have effect on non-capital cities.

Table 8 is also interesting for the carbon price effect on inspections. Table 7 reveals the puzzle of the inspection effect on regions covered by ETS that have higher pollution during inspections. Table 8 explains the phenomenon by the interaction term. Higher carbon price during inspections raises the carbon emission during inspections for cities covered by but without carbon ETS. That is to say, cities around provincial capitals, which are always the first station of inspections, increase their emission when the demand for carbon allowance is high.

The high demand for carbon prices during inspections has implications for firms' behavior. It means most players in the region are chasing for carbon allowance which will help them to avoid punishment by inspections. Inspection teams, as the analysis in section 5 mentions, will punish air pollution but are aware of carbon ETS. Better carbon ETS will satisfy their aims as they are supported by MEE. Therefore, the best strategy for firms is to have less pollution during inspections. And the sub-optimal strategy is to have enough carbon allowance which will cover their pollution during inspections.

However, traveling inspections never arrive at a non-capital city at the first station which means all other cities, covered by carbon ETS, will do their best to prepare for the inspections. They will drive up the carbon price and clean up their future pollution plan, which means they will have high pollution during days in which the province is covered by inspections but the team has not come to the city. It is another mouse and cat game but the carbon market presents as a final insurance for firms. More importantly, cities and firms do not always have pollution before and after the arrival of inspection at risk. As column 1 has shown, only when the carbon price is high which means firms already have a high pollution plan during the period will they have over-emission at risk. When the carbon price and demand are low, firms will not have pollution during the inspections as they will not be punished without a high pollution plan. The over-pollution related to carbon demand and inspection is a new government failure produced by carbon ETS.

### *6.4 Robustness checks*

For the robustness check, we rerun the models presented in Table 3, columns 3 and 6, using alternative windows for turnovers ranging from 3 to 30 days. The results are presented in Tables 9 and 10. Table 9 focuses on cities covered by the Carbon ETS and shows that the turnover effect remains robust for windows ranging from 3 to 15 days. This effect leads to a reduction in the air quality of up to 2.94% with a significance level of 1%. However, the turnover effect disappears for longer windows of 30 days. The coefficient for *Carbon ETS (Covered) * Turnover* is significant for windows of 7, 9, and 30 days. Its influence ranges from 5.04% for seven days to 3% for 30 days. Furthermore, the inspection effect and its interaction term with Carbon ETS remain robust under alternative windows for turnovers.

Table 10 shows that, with *Carbon ETS (Location)*, the turnover effect is similarly robust and remains significant even for windows up to 30 days. However, Carbon ETS appears to affect air quality during turnovers with more extended periods positively. The coefficient of *Carbon ETS (Covered) * Turnover* is significant even for windows of 30 days, and it leads to an 10% improvement in air quality. This finding is consistent with the reality in political centres where agents are more cautious and patient under uncertainty. Moreover, the inspection effect remains similarly robust to that in Table 8.

Secondly, we use alternative measures for the tests in Tables 3 and 5. Specifically, we use PM2.5, which was newly included in the 2012 standard of AQI. Table 11 presents the test results for Table 3 with the independent variable of the logarithm of PM2.5. The results are very similar to those shown in Table 3. Cities covered by or located in the Carbon ETS differ regarding their PM2.5 concentration during turnover windows. However, when controlling for the interaction between turnover shock and Carbon ETS, the results indicate that Carbon ETS significantly reduces the PM2.5 concentration during turnover windows. This effect ranges from 13.44%, stronger for cities where ETS is located, to cities covered by ETS. Carbon ETS also changes the PM2.5 concentration during inspections, as cities emit more during inspections when ETS is present. The only difference between Table 3 and Table 11 is that *Carbon ETS (Location) * Inspection* is significantly positive in Column 6 of Table 11. Therefore, compared with AQI, PM2.5 is more influenced by Carbon ETS for cities where ETS is located during inspections. Table 12 shows that the RD model has similar results to those presented using AQI for PM2.5.

In Table 8, we apply carbon price to prove the essentiality of efficient carbon market condition. However, the endogenous problem remains a concern for the carbon price. Much evidence has shown that carbon price may be influenced by weather and air quality. We draw the concern by following analysis. Firstly, the causality from air quality to carbon price is mostly longer period. Most research on how air quality influence carbon price relies on the government intervention for pollution which requires a period for policy execution(Han et al. 2019). Also, existing literature indicates that government intervention induce a positive relation between carbon price and AQI (Zhou and li, 2019; Wen et al. 2022; Zhu et al. 2022). But it is not reasonable when the causality reverses. Since Table 8 reveals a negative relation between carbon price and AQI instead. Firms reduce production and emission when the carbon is not affordable. But good air quality will not drive up their demand on carbon.

Finally, we conduct further empirical works to draw the concern. In Table 13, we applies three strategies to eliminate the reverse causality problems. In column 1 and 2, we use lag 1 term carbon price and  In column 3 and 4, we use lag 1 to 3 terms average carbon price which are unlikely to be influenced by future air quality. In column 5 and 6, we use the residual of lag 1 to 3 carbon price which is the regression residual of carbon price on weather conditions and air quality. Interestingly, we find the carbon price remain a significantly negative effect on carbon emission in nearly all columns which means higher carbon price indeed reduce carbon emission. And it can also reduce political uncertainty effect induced by inspections and turnovers.

## Table 9. Robustness Check with Alternative Windows-Focusing on Carbon ETS(Covered)

The table reports the results of DID regressing log air quality indicators against a dummy for political uncertainty(Turnover), an interaction term between Turnover and Carbon ETS. Turnover is 1 for days in the 3,7,9,15 and 30 days before local leaders' turnover for column 1 to 5. Carbon ETS(Covered) is one if the city has been covered by one of the eight provincial Carbon ETS. Standard errors are clustered at the city level. Robust t-statistics are in parenthesis. ***, **, and * correspond to statistical significance at 1%,5% and 10% levels respectively.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | [-3,0) | [-7,0) | [-9,0) | [-15,0) | [-30,0) |
| Turnover | 0.0265*** | 0.0294*** | 0.0240*** | 0.0188*** | 0.0107 |
| | (2.69) | (3.60) | (3.12) | (2.62) | (1.60) |
| Inspection | -0.0591*** | -0.0590*** | -0.0590*** | -0.0590*** | -0.0591*** |
| | (-7.38) | (-7.37) | (-7.37) | (-7.36) | (-7.37) |
| Sunshine | -0.0002* | -0.0002* | -0.0002* | -0.0002* | -0.0002* |
| | (-1.87) | (-1.88) | (-1.88) | (-1.88) | (-1.88) |
| Precipitation | -0.0006*** | -0.0006*** | -0.0006*** | -0.0006*** | -0.0006*** |
| | (-21.68) | (-21.68) | (-21.68) | (-21.68) | (-21.68) |
| Wind Speed | -0.0057*** | -0.0057*** | -0.0057*** | -0.0057*** | -0.0057*** |
| | (-12.37) | (-12.37) | (-12.37) | (-12.37) | (-12.37) |
| Humidity | -0.0024*** | -0.0024*** | -0.0024*** | -0.0024*** | -0.0024*** |
| | (-5.30) | (-5.30) | (-5.30) | (-5.30) | (-5.30) |
| Temperature | 0.0015*** | 0.0015*** | 0.0015*** | 0.0015*** | 0.0015*** |
| | (12.77) | (12.78) | (12.78) | (12.79) | (12.79) |
| Carbon ETS(Covered) | 0.0015 | 0.0020 | 0.0022 | 0.0022 | 0.0031 |
| | (0.07) | (0.10) | (0.11) | (0.10) | (0.15) |
| Carbon ETS(Covered)*Turnover | -0.0239 | -0.0504** | -0.0487** | -0.0292 | -0.0300* |
| | (-1.01) | (-2.20) | (-2.18) | (-1.43) | (-1.72) |
| Carbon ETS(Covered)*Inspection | 0.0552*** | 0.0551*** | 0.0552*** | 0.0553*** | 0.0557*** |
| | (3.56) | (3.56) | (3.56) | (3.57) | (3.61) |
| City FE | Yes | Yes | Yes | Yes | Yes |
| Month FE | Yes | Yes | Yes | Yes | Yes |
| Holiday | Yes | Yes | Yes | Yes | Yes |
| N | 511760 | 511760 | 511760 | 511760 | 511760 |
| R2 | 0.4891 | 0.4892 | 0.4892 | 0.4892 | 0.4892 |

## Table 10. Robustness Check with Alternative Windows -Focusing on Carbon ETS(Location)

The table reports the results of DID regressing log air quality indicators against a dummy for political uncertainty(Turnover), an interaction term between Turnover and Carbon ETS. Turnover is 1 for days in the 3,7,9,15 and 30 days before local leaders' turnover for column 1 to 5. Carbon ETS(location) is one if the city has a provincial Carbon ETS. Standard errors are clustered at the city level. Robust t-statistics are in parenthesis. ***, **, and * correspond to statistical significance at 1%,5% and 10% levels respectively.

| | (1)<br>[-3,0) | (2)<br>[-7,0) | (3)<br>[-9,0) | (4)<br>[-15,0) | (5)<br>[-30,0) |
|---|---|---|---|---|---|
| Turnover | 0.0230** | 0.0246*** | 0.0197*** | 0.0172** | 0.0088 |
| | (2.58) | (3.23) | (2.73) | (2.55) | (1.43) |
| Inspection | -0.0518*** | -0.0518*** | -0.0518*** | -0.0518*** | -0.0518*** |
| | (-6.80) | (-6.79) | (-6.79) | (-6.79) | (-6.78) |
| Sunshine | -0.0002* | -0.0002* | -0.0002* | -0.0002* | -0.0002* |
| | (-1.86) | (-1.87) | (-1.87) | (-1.87) | (-1.86) |
| Precipitation | -0.0006*** | -0.0006*** | -0.0006*** | -0.0006*** | -0.0006*** |
| | (-21.65) | (-21.65) | (-21.65) | (-21.65) | (-21.64) |
| Wind Speed | -0.0057*** | -0.0057*** | -0.0057*** | -0.0057*** | -0.0057*** |
| | (-12.37) | (-12.37) | (-12.37) | (-12.37) | (-12.37) |
| Humidity | -0.0024*** | -0.0024*** | -0.0024*** | -0.0024*** | -0.0024*** |
| | (-5.30) | (-5.30) | (-5.30) | (-5.30) | (-5.30) |
| Temperature | 0.0015*** | 0.0015*** | 0.0015*** | 0.0015*** | 0.0015*** |
| | (12.76) | (12.76) | (12.76) | (12.77) | (12.78) |
| Carbon ETS(Location) | -0.0197 | -0.0181 | -0.0174 | -0.0161 | -0.0131 |
| | (-0.48) | (-0.44) | (-0.43) | (-0.40) | (-0.32) |
| Carbon ETS(Location)*Turnover | -0.0035 | -0.0934*** | -0.1048*** | -0.0985*** | -0.0976*** |
| | (-0.08) | (-2.92) | (-3.49) | (-2.92) | (-3.39) |
| Carbon ETS(Location)*Inspection | 0.0465 | 0.0460 | 0.0465 | 0.0492 | 0.0628 |
| | (1.10) | (1.09) | (1.10) | (1.16) | (1.53) |
| City FE | Yes | Yes | Yes | Yes | Yes |
| Month FE | Yes | Yes | Yes | Yes | Yes |
| Holiday | Yes | Yes | Yes | Yes | Yes |
| N | 511760 | 513422 | 511760 | 511760 | 511760 |
| R2 | 0.4891 | 0.489 | 0.4891 | 0.4891 | 0.4892 |

## Table 11. Robustness Check with PM2.5 as the Alternative Measurement

The table reports the results of DID regressing log PM2.5 concentration against a dummy for political uncertainty(Turnover), an interaction term between Turnover and Carbon ETS. Turnover is 1 for days in the week before local leaders' turnover. Carbon ETS(Covered) is one if the city has been covered by one of the eight provincial Carbon ETS. Carbon ETS(location) is one if the city has a provincial Carbon ETS. Column 1 uses the subsample of only regions finally covered by eight provincial carbon ETS. Column 4 uses the subsample of cities with Carbon ETS finally. Standard errors are clustered at the city level. Robust t-statistics are in parenthesis. ***, **, and * correspond to statistical significance at 1%,5% and 10% levels respectively.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Regions Covered by Carbon EST | Other | All | Cities with Carbon EST | Other | All |
| Turnover | -0.0046 | 0.0270** | 0.0335*** | -0.0377 | 0.0266** | 0.0278*** |
| | (-0.21) | (2.40) | (2.95) | (-1.29) | (2.51) | (2.62) |
| Inspection | 0.0586*** | -0.0880*** | -0.0949*** | 0.0459 | -0.0804*** | -0.0816*** |
| | (2.88) | (-7.64) | (-8.23) | (0.84) | (-7.52) | (-7.64) |
| Sunshine | -0.0001 | -0.0009*** | -0.0007*** | 0.0005 | -0.0007*** | -0.0007*** |
| | (-0.43) | (-6.38) | (-5.16) | (0.85) | (-5.41) | (-5.13) |
| Precipitation | -0.0006*** | -0.0011*** | -0.0010*** | -0.0008*** | -0.0010*** | -0.0010*** |
| | (-7.69) | (-27.43) | (-25.96) | (-3.93) | (-25.83) | (-25.90) |
| Wind Speed | -0.0166*** | -0.0102*** | -0.0109*** | -0.0188*** | -0.0107*** | -0.0109*** |
| | (-13.17) | (-16.02) | (-17.66) | (-10.62) | (-17.32) | (-17.66) |
| Humidity | -0.0037 | 0.0018*** | 0.0010 | 0.0075 | 0.0008 | 0.0010 |
| | (-1.32) | (2.72) | (1.53) | (1.15) | (1.24) | (1.53) |
| Temperature | 0.0023*** | 0.0018*** | 0.0017*** | 0.0028*** | 0.0017*** | 0.0017*** |
| | (6.52) | (9.88) | (10.26) | (4.90) | (10.08) | (10.25) |
| Carbon ETS(Covered) | | | 0.0277 | | | |
| | | | (1.11) | | | |
| Carbon ETS(Covered)*Turnover | | | -0.0639** | | | |
| | | | (-2.02) | | | |
| Carbon ETS(Covered)*Inspection | | | 0.1074*** | | | |
| | | | (5.24) | | | |
| Carbon ETS(location) | | | | | | 0.0082 |
| | | | | | | (0.17) |
| Carbon ETS(Location)*Turnover | | | | | | -0.1344*** |
| | | | | | | (-3.31) |
| Carbon ETS(Location)*Inspection | | | | | | 0.1228** |
| | | | | | | (2.48) |
| City FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Holiday | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 78,816 | 432,888 | 511,704 | 16,794 | 496,572 | 511,704 |
| R2 | 0.5038 | 0.5327 | 0.5229 | 0.4628 | 0.5258 | 0.5228 |

**Table 12. Robustness Check with PM2.5 as the Alternative Measurement RD**

The table reports the results of non-parametric RD estimate log PM2.5 concentration against a dummy for political uncertainty(Turnover), an interaction term between Turnover and Carbon ETS using symmetric windows of 7 days before turnover and seven days after the turnover. Turnover is 1 for days in the week before local leaders' turnover. Carbon ETS(Covered) is one if the city has been covered by one of the eight provincial Carbon ETS. Carbon ETS(location) is one if the city has a provincial Carbon ETS. Column 1 and 4 does not include time trends. Columns 2 and 5 use linear time trends. Columns 3 and 6 use linear and quadratic time trends. Standard errors are clustered at the city level. Robust t-statistics are in parenthesis. ***, **, and * correspond to statistical significance at 1%,5% and 10% levels respectively.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Turnover | -0.019 | -0.02 | -0.03* | -0.019 | -0.02 | -0.03* |
| | (-1.06) | (-1.13) | (-1.85) | (-1.07) | (-1.13) | (-1.85) |
| Local Polynomial | Linear | Linear | Linear | Quadratic | Quadratic | Quadratic |
| Kernel | Tri. | Epa. | Uni. | Tri. | Epa. | Uni. |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| City FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Holiday | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 17,094 | 17,094 | 17,094 | 17,094 | 17,094 | 17,094 |

## Table 13. Robustness Check Using Different Forms of Carbon Price

The table reports the results of DID regressing log AQI concentration against a dummy for political uncertainty(Turnover and Inspection), an interaction term between Turnover and different forms of Carbon Price, an interaction term between Inspection and different forms of Carbon Price, weather controls, city, monthly and holiday fixed-effects. Turnover is 1 for days in the week before local leaders' turnover. Inspection is 1 for days when the region is covered by inspections. Carbon ETS price is the lag 1 close price of local carbon ETS for column 1 and 2, average close price for the last three days for column 3 and 4, and the residual of average close price for the last three days for column 5 and 6. Standard errors are clustered at the city level. Robust t-statistics are in parenthesis. ***, **, and * correspond to statistical significance at 1%,5% and 10% levels respectively.

| | Carbon Price t-1 | | Average Carbon Price of [t-1:t-3] | | Average Residual of [t-1:t-3] | |
|---|---|---|---|---|---|---|
| | Regions Covered by Carbon ETS (1) | Cities with Carbon ETS (2) | Regions Covered by Carbon ETS (3) | Cities with Carbon ETS (4) | Regions Covered by Carbon ETS (5) | Cities with Carbon ETS (6) |
| Turnover | 0.037 | 0.075 | 0.054 | 0.046 | -0.009 | 0.001 |
| | (0.94) | (0.84) | (1.44) | (0.53) | (-0.56) | (0.02) |
| Inspection | -0.039** | -0.100 | -0.54*** | -0.111 | 0.016 | -0.038 |
| | (-2.01) | (-1.45) | (-3.15) | (-1.44) | (1.31) | (-0.53) |
| Carbon Price | -0.003*** | -0.003*** | -0.003*** | -0.002*** | -0.001** | -0.002 |
| | (-5.56) | (-2.61) | (-4.73) | (-2.14) | (-2.11) | (-1.47) |
| Carbon Price*Turnover | -0.003 | -0.003 | -0.003* | -0.003 | -0.004 | -0.013 |
| | (-1.46) | (-1.28) | (-1.86) | (-0.86) | (-0.71) | (-1.31) |
| Carbon Price*Inspection | 0.003*** | 0.002** | 0.004*** | 0.004*** | 0.006*** | 0.006* |
| | (4.27) | (2.06) | (6.19) | (2.83) | (5.78) | (1.70) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| City FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Month FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Holiday | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 36,580 | 6,091 | 57,114 | 9,914 | 57,114 | 9,914 |
| R2 | 0.50 | 0.46 | 0.49 | 0.45 | 0.49 | 0.45 |

## 7. Conclusions and Policy Implications

Our research offers an optimal case for achieving a delicate balance between market mechanisms and government intervention in carbon policy. Specifically, the Chinese carbon Emission Trading Scheme (ETS) stands out as a noteworthy example of a government-led market, imposing mandatory responsibilities on firms to address market failures. The success and evolution of the Chinese carbon ETS pilot scheme hold significant implications. It represents a commendable incremental improvement made by a follower, drawing on the cap system integrated into China's pollution regulation since 2009. Building on the success of the EU ETS, China's ETS was established in 2011 as a cap-and-trade system. Drawing from the experiences of developed countries, the Chinese ETS pilot scheme effectively mitigated government failures associated with cap system regulation, as detailed in the preceding analysis.

Notably, this ETS market introduced alternative tools for fostering competition among local governments, thereby stimulating market development. The outcomes of this competition are substantial; over a decade, China has accumulated valuable experience in ETS market operations, particularly focusing on core industries. The controlled competition, initiated with only seven players permitted by the central government, has prevented cut-throat competition and potential market failures. The noteworthy winners of this competition, Wuhan and Shanghai, have not only benefited from industrial synergy but also received political promotion.

Moreover, the establishment of the carbon ETS in China is not solely the result of well-designed market institutions; it is also a product of gradual reform, decentralized allocation, and central inspections. While acknowledging that the current Chinese ETS market faces challenges like fraud and collusion, it nevertheless provides invaluable lessons for developing countries grappling with both market and government failures.

ETS effectively addresses both market and government failures in carbon emission control by harnessing the power of market incentives and aligning them with policy targets. ETS helps overcome market failures by creating a price signal for carbon emissions, internalising the environmental costs associated with emitting greenhouse gases and stimulates technological innovation and encourages the development of low-carbon solutions. Meanwhile, ETS provides firms with the flexibility to choose how to reduce their emissions, allowing them to respond to market conditions and technological advancements. This flexibility helps to overcome the information and knowledge gaps that often characterise government interventions, ensuring that emission reductions are achieved in the most economically efficient way. Moreover, ETS can be adapted over time to reflect changing policy goals, market conditions, or scientific knowledge, ensuring that the policy remains relevant and effective in addressing the evolving challenge of climate change.

The findings in this paper provide empirical support for the effectiveness of ETS in addressing both market and government failures in carbon emission control. The analysis of the two natural experiments – unannounced inspections by the central government and turnovers of senior local government officials – demonstrates that cities with ETS exchanges are less responsive to these political events, suggesting that the ETS system helps to mitigate the impact of political uncertainty on emission control efforts. ETS effectively addresses both market and government failures in carbon emission control by combining market incentives with policy targets. The flexibility, adaptability, and innovation-driven nature of ETS, coupled with its potential to foster international cooperation, make it a powerful tool for achieving emission reduction goals in an efficient and equitable manner.

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