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Research article

Political incentives in market-based environmental regulation: Evidence from China's carbon emissions trading scheme

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ABSTRACT

This paper used a multi-period DID model with panel data from 283 Chinese cities between 2006 and 2019 to investigate the emission reduction effects and mechanisms of China's carbon trading scheme. The research revealed that China's Carbon Emissions Trading Scheme not only stimulated businesses to reduce emissions as a market-based environmental regulation policy but also influenced local governments' governance objectives. As a result, the Hawthorne effect inevitably manifested during the experimental period of China's Carbon Emissions Trading Scheme. Further analysis indicated that China's CETS encouraged local authorities to take a more proactive stance towards the balance between environmental preservation and economic growth, aiming to achieve a mutually beneficial outcome. Based on the political stance of local governments, they are likely to simultaneously increase their focus on both economic growth and environmental protection. However, when faced with the conflict between economic advancement and environmental safeguarding, pilot regions prioritized ecological conservation in their practical steps, leading to a modest decline in economic growth. In other words, the government's high-profile announcements may not always manifest in actual deeds. In practice, local authorities tend to allocate more administrative resources to areas highly prioritized by the central government. Furthermore, the extended analysis reveals that China's CETS has resulted in a reduction in social welfare due to a shift in governance priorities influenced by political incentives. Therefore, fine-tuning the performance evaluation mechanism, preventing any bias towards the target preferences of local authorities, and guaranteeing the successful operation of the market mechanism are imperative to achieve truly low-cost and sustainable emissions reductions objectives for CETS.

1. Introduction

In order to control greenhouse gas emissions at a lower cost, China's 12th Five-Year Plan proposed that it would gradually establish a domestic carbon trading market. Then in October 2011, China approved a Carbon Emissions Trading Scheme (CETS), which would be firstly piloted in 7 provinces and cities, and subsequently succeeded in operating between 2013 and 2014. In 2016, Fujian and Sichuan provinces also joined the pilot program. After nearly a decade of policy experimentation, the Chinese government decided to extend this CETS policy from pilot areas to the whole country in July 2021. Obviously, compared to a carbon tax, which has been

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discussed but not put into practice, the Chinese government believes that pilots over the past decade have proven that CETS can help China control carbon emissions at a lower economic cost. Nevertheless, considering China's unique political and economic system, the combination of effective government and efficient market [1], government behavior exerts substantial influence on the functioning of the market. Thus, it remains questionable whether CETS, as a policy experiment, relies purely on market incentives to achieve carbon emission reductions. Based on this, it is doubtful that the successful experience of the pilot phase can be generalized to the whole country. As a matter of fact, in China's progressive reforms in the past, there have been many policy experiments driven by pilots, and there have been many cases in which the pilots have been successful but the extension has failed [2].

Theoretically speaking, as a market-based policy instrument, CETS is an institutional arrangement with the advantages in lower cost, emission-reduction effectiveness, political acceptability [3–5]. Since the European Union adopted the CETS to control carbon emissions, many developed countries started to follow suit and yielded remarkable results in practice [5–8]. From this point of view, China's CETS should also be able to achieve significant emission reductions. Nonetheless, the viability of the carbon trading system hinges on the efficient functionality of the market system [9]. There remains uncertainty regarding the extent to which the effectiveness of the CETS policy in developed countries can be replicated in developing nations marked by incomplete market mechanisms. Some studies have proved that China's CETS has effectively played a role in reducing emissions [10–13], and elaborated its mechanism from the following aspects such as green innovation [14,15], energy consumption [12,16], and industrial structure [12,15]. However, it is still difficult to determine whether these effects entirely come from market incentives. In particular, some studies also show that China's carbon trading market is characterized by low price, low activity and low liquidity [17–19]. Evidently, the aforementioned details have increased people's skepticism over whether China's CETS actually produces emission reductions in line with the market mechanism.

Building upon this suspicion, for probing potential non-market drivers underlying the abatement impact of CETS in China, several studies have initiated an exploration into the impact of governmental actions. Some studies have indicated that China's CETS emission reduction performance correlates with administrative intervention: the greater the administrative intervention, the more pronounced the emission reduction effect [19–21]. In these studies, various indicators were selected as proxies for local government administrative intervention, including the proportion of state-owned enterprises, fiscal dependence [20], the number of environmental enforcement officers [21], and emissions reduction pressure [19]. These variables were incorporated into the analysis as exogenous factors assumed to be unaffected by policies. Given that CETS policy operates on market principles, a pertinent question arises: why does government intervention enhance the emission reduction effectiveness of China's CETS? Alternatively, what are the mechanisms and underlying political incentives that drive government intervention in this context? This suggests that local government's administrative intervention in carbon emissions governance may not be entirely exogenous; instead, it may be influenced to some extent by the policy experiment of CETS. Therefore, its inclusion as a moderator in the empirical model may be subject to scrutiny. In reality, within China's administrative system, lower-level governments are accountable to higher-level governments and must align their actions with the objectives set by those at higher administrative levels. According to certain research, political signal plays a role in the carbon market's ability to reduce emissions [22]. In this way, a potential explanation for the use of administrative intervention by local governments in the CETS pilot seems to have emerged. As a policy experiment, the market-based environmental regulation policy sends a clear political signal to emphasize the importance that the central government places on carbon emission reduction. And so it was. In August 2014, the General Office of the State Council issued the "Guiding Opinions on Further Promoting the Pilot Project of Paid Use and Trading of Pollutant Emission Rights". According to this document, the pilot provinces must annually report to the State Council on the most recent status of the pilot work; the Ministry of Finance and other pertinent authorities should simultaneously monitor and compile the experiences and practices of the pilot locations. Building upon the aforementioned facts and analysis, we have grounds to assert that China's CETS creates incentives for emission reduction through non-market mechanisms, thereby enhancing its effectiveness in reducing carbon emissions.

To delve into the fundamental drivers of these non-market incentives, an exploration of China's distinctive political and economic systems is essential. The intricate interplay between the government and the market stands as a significant hallmark of China's economic development. Grasping the underlying rationale and precise mechanisms by which the Chinese government formulates and executes its policies — essentially, how the grassroots government adjusts its own work objectives in response to shifts from higher-level goals for the better— emerges as the linchpin for comprehending China's economic landscape and effectively narrating its story [2]. China, as a unitary state, has a highly centralized administrative system, so the central government has dominant power over the turnover of local officials [23]. Given this background, the CETSs may be stimulated by both market and political factors when they are implemented as pilot projects, resulting in significant emission reduction effects. On one hand, CETS functions as an environmental regulatory policy rooted in market mechanisms, inherently subjecting its emission reduction outcomes to market laws. On the other hand, the advancement of local officials hinges on evaluations of their governance competence and allegiance by higher government authorities. Consequently, local officials tend to allocate more administrative resources to those tasks esteemed by the central government. Following the attainment of initial results through the China's CETS policy, the nationwide implementation phase ensues. However, the capacity to replicate emission reductions on the same scale as those observed during the experimental phase of the policy will be influenced by two key factors. In terms of market logic, the initial goal of this policy is to achieve carbon emission reduction through market incentives, which will not disappear as the scope of policy implementation expands from pilot areas to the whole country. In terms of political logic, upon the complete implementation of the pilot policy, the distinctive experimental status of the pilot region ceases to exist, potentially leading to the dissipation or attenuation of the associated political incentives. This is why some pilot policies have been successful in the pilot areas and have faded as soon as they have been rolled out, i.e., the validity of pilot policies is interfered with Hawthorne effect[1] [24]. Broadly speaking, advancing reforms through pilot projects can aid in mitigating the potential risks of policy innovation. However, the precision of policy effect evaluations is concurrently compromised by selection bias and the Hawthorne effect. Consequently, upon the full implementation of the pilot policy, attaining the effects observed during the experimental phase of the policy might not be feasible [25].

Based on the aforementioned analysis, this study employs a multi-period Difference-in-Differences (DID) model to delve into the mechanisms of China's CETS pilot policy, particularly focusing on the logic behind government intervention. We use a dataset encompassing 283 prefecture-level cities in China over the period 2006 to 2019. Fig. 1 illustrates the distinctive aspect of this study in contrast to previous research. It examines both market incentives (i.e., the policy effect), which aligns with expectations for a market-based environmental regulation policy and has been the primary focus of numerous studies in the literature, and, more significantly, it delves into endogenous political incentives (e.g., the Hawthorne effect or the pilot status effect). This perspective has not yet been explored in current research on this issue. This is particularly significant due to the centralized administrative system in which lower levels of government are obligated to act in accordance with the goals set by higher levels of government. Therefore, instead of treating government intervention as an exogenous moderating variable, as is customary in the literature, this paper regards it as an endogenous variable influenced by policy. Regarding the political incentives generated by China's CETS as a policy experiment, this paper reveals that the pilot policy prompted local governments to make initial political commitments. However, their subsequent actions may not have been consistent with these earlier statements at all times. Furthermore, taking into account that local governments in China typically grapple with multifaceted responsibilities, necessitating the allocation of administrative resources across various objectives like economic growth, environmental protection, and public welfare, an increased emphasis from higher-tier governments on one particular task might result in a decreased focus on other responsibilities [26]. The findings of this paper further confirm these conclusions. In the main body of the paper, we only examine the trade-offs between environmental goals (carbon emissions and PM2.5) and economic growth. To further ascertain if similar trade-offs exist with other objectives, the paper delves into an extended analysis, exploring the social welfare implications of China's CETS. In this supplementary analysis, the study uncovers that, given limited administrative resources, carbon emission reduction efforts result in welfare losses, a scenario that theoretically shouldn't occur for a market-based environmental regulatory policy. This phenomenon provides further evidence that within administrative systems like China's, even environmental governance policies rooted in market mechanisms tend to be influenced by political incentives. Moreover, the extended analysis reveals that China's CETS might be associated with a pollution paradise effect. Collectively, these findings underscore that political incentives, rather than market incentives, may be the primary drivers behind the emission reductions observed in a policy experiment such as China's CETS.

Overall, three contributions are made as follows.

First and foremost, in contrast to previous studies that have primarily emphasized market incentives, this paper delves deeply into the endogenous political incentives that drive the effectiveness of China's CETS pilot policies. It is important to emphasize that this paper's exploration of political incentives differs from existing research, which often treats government intervention as an exogenous variable [19–21]. Within China's highly centralized political system, lower-level governments are obligated to align with the objectives set by higher-level governments. This fresh perspective enriches our understanding of how local governments respond to the political signals from the central government regarding carbon emission reduction. This paper challenges the traditional approach of considering government intervention as an exogenous moderating variable. Instead, it treats government intervention as an endogenous variable influenced by policy, marking a significant departure from previous studies. This perspective suggests that local governments' behavior in carbon emission governance is not entirely exogenous but is influenced to some extent by the CETS policy experiments. This innovative approach provides a novel perspective on the dynamic relationship between government behavior and environmental governance outcomes. In sum, this paper successfully confirms the presence of the Hawthorne effect. The study finds that policy pilots generate additional incentives that prompt local governments to make extra efforts in response to the preferences of higher-level governments. This strategic effort renders the policy pilot experience non-representative [2]. Given that China is the world's largest carbon emitter, the ability to control carbon emissions at a lower cost is of paramount importance for global climate governance cooperation. Therefore, as the Chinese government considers policy promotion, it should thoroughly evaluate the potential impact of local governments' strategic actions on policy effectiveness.

Secondly, when investigating the endogenous political incentives behind China's CETS emission reduction effects, this paper examines whether there is substitutability between the two major objectives of environmental governance and economic growth, taking into consideration the premise of multi-task constraints faced by local governments. Moreover, given that, in political practice, local governments often need to make political statements about the governance objectives proposed by higher-level governments before translating them into concrete actions, a scenario where information asymmetry can make it challenging for higher-level governments to rigorously assess the actual efforts and effectiveness of local governments in achieving certain governance goals. This situation can lead to disparities between political statements and practical actions, a phenomenon affirmed by the findings in this paper. Given the central government's aspiration to achieve a mutually beneficial outcome for both economic development and carbon emission

[1] The Hawthorne effect is a type of reactivity in which individuals modify an aspect of their behavior in response to their awareness of being observed (From Wikipedia: https://en.wikipedia.org/wiki/Hawthorne_effect). In this paper, the Hawthorne effect can be understood as the result of the local governments in the pilot areas' responses to the pilot policies when they realize that they are the observed subjects.

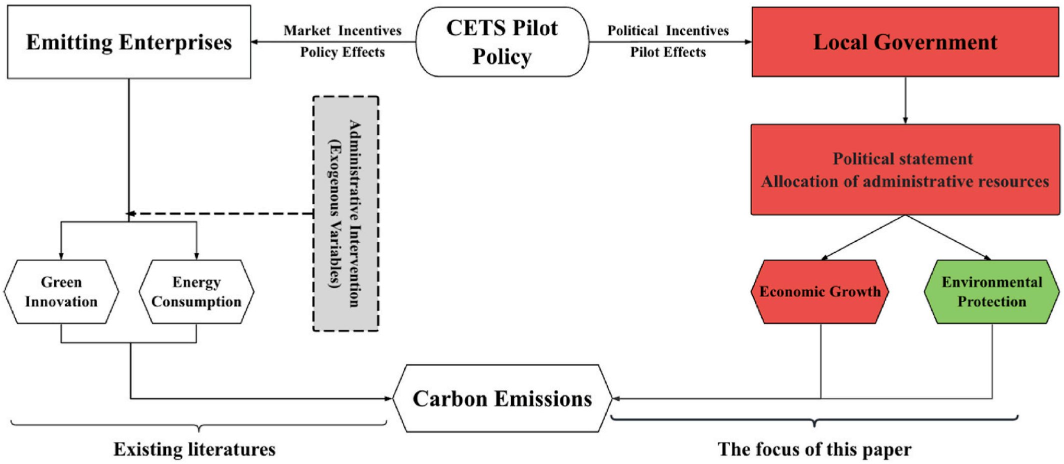

Fig. 1. The emission reduction mechanism of China's CETS pilot policy.

reduction objectives through CETS, this political signal prompts local governments within the treatment group to express strong commitment to both goals in their political statements. However, operating within the constraint of limited administrative resources, which cannot be instantaneously altered, local governments are compelled to prioritize the goal that garners more attention from their superiors in their practical endeavors. This necessitates the allocation of administrative resources away from other governance objectives to ensure that the goal receiving more attention from higher authorities is given priority [26]. In the extended analysis section, this paper further explores the influence of China's CETS on local governments' strategic goal management behavior and its repercussions on social welfare. The study reveals that, within the confines of limited administrative resources, efforts to reduce carbon emissions may result in welfare losses, a divergence from expectations associated with market-based environmental policies.

Thirdly, this study introduces some innovations in the sample selection and carbon emission measurement. Prefectural municipal governments, acting as representatives of provincial governments and administrators of county governments, hold a central position within China's administrative management system [27]. Therefore, we utilize data from prefectural-level cities, in contrast to the provincial-level data commonly used in most studies. Although some prior research has examined this issue at the prefecture-level, the methods employed to measure carbon emissions in these studies might lack precision. For instance, some studies have employed weightings derived from nighttime lighting data to disaggregate provincial-level carbon emissions data based on energy consumption to the municipal level. Despite being the closest approximation to actual circumstances, this method could still introduce significant errors due to variations in economic and industrial structures across regions. Consequently, we adopt the approach proposed by Wu et al. (2021), directly aggregating county-level carbon emission data, based on nighttime lighting data, to the city level [20,28]. Simultaneously, for missing data from the year 2018 onward, we incorporate the average growth rate in line with the approach by Hong et al. (2022) to update the data up to 2019 [29], thereby expanding the size of our analytical sample.

In combination, these innovations offer a fresh perspective on the dynamics between political and market incentives in China's CETS pilot policy and provide valuable insights into the potential drivers behind the observed emission reductions. The remainder of this paper is organized as follows: Section 2 is a literature review on the emission reduction effect and its mechanism of China's Carbon Emissions Trading Scheme; Section 3 is the policy introduction, institutional background and research hypothesis; Section 4 introduces methods, variables, and data sources. Section 5 is the discussion of the regression results; Section 6 presents an extended analysis; The last section is the conclusion and policy recommendations.

2. Literature reviews

2.1. Effectiveness and mechanisms of carbon market

Has the CETS policy in China effectively reduced carbon emissions in the pilot areas? This question has been a prominent topic in the realm of environmental economics for several years. According to existing research, China's carbon trading market has indeed led to a reduction in carbon emissions across various levels, including provinces, cities, industries, and enterprises [19]. In conclusion, there is a consensus among existing studies regarding the emission reduction effect of China's CETS pilot policy [12,30–33]. Building upon this foundation, the prior studies have also examined the emission reduction mechanism of China's CETS from a market-oriented perspective. In general, although the selection of research sample varies, the existing studies about the emission reduction mechanism of CETS can be summarized into three primary aspects:

The first facet centers on technological advancement or green innovation. Empirical investigations have revealed that China's CETS pilot policy stimulated green innovation within enterprises [34], consequently leading to diminished carbon emissions and carbon intensity in the pilot regions [35]. This underscores the pivotal mediating role played by technological progress and green innovation in the carbon reduction outcomes of CETS policies [36]. Furthermore, subsequent research indicates that the affirmative impacts of

China's CETS policy on enterprise innovation predominantly manifest in quantitative and lower-quality innovation, with incentives for high-quality innovation primarily arising within state-owned enterprises, large corporations, and those situated in the eastern region [37]. In essence, the aforementioned inquiries are concerned with the influence of the CETS policy on the conduct of carbon-emitting companies. Enterprises are governed by the laws of the market, and they undertake green innovation to obtain emission reduction dividends through the carbon market. It is apparent that these studies fail to consider the role of local governments in reducing carbon emissions.

The second aspect centers on energy consumption or energy structure. Certain research contends that within the context of China's carbon trading pilot policy, enterprises often opt for reducing output instead of intensifying green technological innovation to attain their emission reduction objectives [14]. Additionally, the energy consumption of regulated industries in pilot regions experiences a notable decline [12]. This indicates that carbon trading markets have the potential to curtail overall energy consumption and reshape energy consumption patterns, thereby triggering emissions reduction [16]. Nonetheless, given the inherent correlation between energy consumption and carbon emissions, the findings of the above studies primarily reinforce the presence of the CETS policy's emission reduction effect, rather than providing a comprehensive understanding of its underlying mechanism. To be precise, explaining the reduction in carbon emissions through energy consumption is more akin to a technical analysis rather than an economic one. This is because, irrespective of the actions taken by companies, the reduction of carbon emissions is consistently achieved by minimizing energy consumption.

The third aspect delves into the impacts on industrial structure. Constrained by market-oriented environmental regulations, the competitive pressure for survival compels high-emission enterprises to contemplate timely transformation and upgrading, lest they face the prospect of market elimination. Several studies have unearthed that China's CETS policy can indeed invigorate the upgrading of the industrial structure [38]. In other words, the advancement or adjustment of industrial structure mediates the reduction of carbon emissions [39,40]. However, the upgrading of the industrial structure is shaped by a confluence of factors. In essence, both the market and the government collaboratively influence shifts in the industrial framework.

In conclusion, the efficacy of China's CETS in curtailing carbon emissions has been substantiated by existing research. Concurrently, these studies have indicated that carbon markets can mitigate carbon emissions through technological innovation, energy consumption adjustments, and industrial structure enhancements. However, existing studies still have shortcomings. The three emission reduction pathways proposed by existing studies do not fundamentally explain the full source of incentives to reduce carbon emissions. Market forces certainly have an impact on corporate behavior, but they are not the only factor. Even if only market forces are considered, it should be recognized that the maturity of market development also affects the performance of CETS. In the policy experimentation phase, China's CETS was still in its infancy. In terms of trading volume, size and liquidity, the market mechanism of China's CETS is deficient [41]. This raises the question of why the carbon market is still significantly reducing carbon emissions given the immature development of the market. In addition, several other studies indicate that the effect of China's CETS programs on carbon emission reduction began in 2011 [20,42,43], when China initially approved the programs, but the regional carbon markets were not operational until 2013 or 2014. This leads to another question: what has led to the carbon abatement effect in this preparatory phase? It is clear that the carbon abatement mechanisms proposed by previous studies, which only consider market mechanisms, are not sufficient to provide a satisfactory answer to this question.

2.2. *Introducing government intervention to analyze emission reduction*

In response to the above issues, the past studies explored the moderating effects of the market mechanism and administrative intervention on the emission reduction effect of China's carbon trading market [19–21]. Their study found that the carbon price and market liquidity, as gauges of the market mechanism, don't exhibit a substantial impact on carbon emissions reduction. Likewise, the relative market transaction scale, while partially explanatory, only accounts for a fraction of the carbon market's effect on emissions reduction. Hence, the market mechanism itself seems to wield limited influence in driving carbon emissions reduction. Intriguingly, deeper investigation of Wu et al. (2021) uncovers a significant relationship: the more pronounced the government's administrative intervention within the carbon market, the more pronounced the carbon emissions reduction effect becomes [20]. This underscores that China's current carbon market is characterized by achieving emissions reduction through a synergistic interplay between the market mechanism and administrative intervention. However, the two indicators as share of state-owned enterprises and fiscal dependence, used by Wu et al. (2021), may not be an accurate measure of the level of government administrative intervention in the carbon emission market. Adopting the level of local emission reduction pressure as a measure of government intervention may be a better choice [19]. There is also literature that uses the number of environmental enforcement officers in each province as a measure of government intervention [21]. Obviously, their introduction of government behavior into the analytical framework of the carbon market emission reduction mechanism is undoubtedly an important innovation from a research perspective. However, these explorations still have shortcomings.

Firstly, the parameters employed by Wu et al. [20], including the carbon trading price and the count of non-zero trading days, as well as those utilized by Lin and Huang [19], such as volume concentration and effective trading days, face challenges in accurately gauging the functioning of the market. Once the above indicators are adopted, the following doubts are inevitable: (1) Is the market system more efficient the higher the carbon price? There seems to be no theory to support this. (2) Is the carbon market better the more frequent the carbon trading activities? In fact, high trading frequency may also mean that companies do not plan their production properly, i.e., there are short-sighted emitters in the market. (3) Trading concentration and market activity are basically two sides of the same coin. The higher the trading concentration, the lower the percentage of effective trading days and the lower the market activity. Therefore, it is only necessary to select one of these two indicators in the study rather than using them simultaneously.

Secondly, the indicators selected by previous studies for analyzing the impact of government intervention may not be sufficiently reasonable. For example, the use of the share of state-owned enterprises and fiscal dependence [20] as proxy variables when analyzing the impact of government intervention may not be ideal [19]. This is because managers of state-owned enterprises, who often hold certain political positions and are not directly part of local government administration, may be less cooperative than private firms when confronted with excessive emission reduction demands from the local government. Measuring the intensity of government intervention using the number of environmental enforcement personnel [21] has limitations as well. Firstly, this indicator only provides provincial-level data, making it unable to capture variations between cities. Moreover, China's strict administrative establishment management means that an increase in the intensity of environmental regulation is likely to involve stronger enforcement rather than an increase in enforcement personnel. Even if there is an increase in enforcement personnel, they may not be reflected in the statistics as they could be considered outside the official establishment. Furthermore, using emission reduction targets from government work reports to measure pressure for emissions reduction [19] is often only accurate at the provincial level. Sub-provincial government reports frequently do not disclose this target. Additionally, even provincial governments tend to reveal emission reduction targets once every five years.

Thirdly, existing studies overlook the institutional context of China as a centralized state. Within this institutional framework, the behavior of local governments is influenced by the policy preferences of higher-level government authorities. While the past studies acknowledge the impact of government behavior on carbon emissions, they treat it as an exogenous variable. This approach may lack precision as it overlooks the impact of obtaining pilot status on local governments' administrative interventions in carbon mitigation actions. Indeed, when we consider the institutional feature of local governments in China being accountable to their superiors, it becomes clear that the environmental competition would affect the behavior of local officials, especially when the central government increases its focus on environmental issues [44]. China's CETS pilot project, as a policy experiment, inevitably affects the action strategies of local officials in environmental competition. This situation is basically the Hawthorne effect [25]. This issue has not been considered in the previous literature on the abatement effects of carbon markets.

3. Theoretical analysis

3.1. Policy introduction

Policy experimentation serves as an effective mechanism for generating institutional innovations. When implementing a new policy, China usually tests it by implementing the policy through a gradual expansion from a specific pilot and tailoring its implementation to suit local conditions [45]. On October 18, 2010, The Central Committee of the Communist Party of China (CPC) proposed the gradual establishment of a domestic carbon trading market through the Recommendations on the Formulation of the Twelfth Five-Year Plan for National Economic and Social Development. Following this, in October 2011, the National Development and Reform Commission (NDRC) approved the launch of carbon emission trading pilots in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen through the Notice on Carbon Emission Trading Pilot Work. According to this NDRC notice, the above pilot districts were selected based on their declarations and work foundations. The mentioned facts suggest that the pilot regions were already informed of their official qualification to conduct experiments on carbon emissions trading policies after October 2011. Furthermore, following the release of the CPC Central Committee's Recommendation in October 2010, these regions had already taken proactive steps to compete for the pilot status. Upon being officially included in the pilot program, each pilot region devised comprehensive measures for managing carbon emission allowances and operating the carbon market [32]. After two to three years of preparation, the carbon emissions trading market in each pilot region was launched successfully between 2013 and 2014. As of 2016, Fujian and Sichuan had voluntarily joined the CETS program as unofficial pilot regions.

In August 2014, the General Office of the State Council released the Guiding Opinions on Further Advancing the Pilot Program for Paid Use and Trading of Pollutant Emission Permits. As stipulated in this document, the pilot provinces are obligated to provide annual reports to the State Council detailing the latest developments in the pilot initiatives. Additionally, the document mandates that the Ministry of Finance and other pertinent departments simultaneously monitor and consolidate the experiences and practices of the pilot regions. This further reinforces the notion underscored in this paper that the central government places significant emphasis on the emission reduction outcomes of the carbon trading market within the pilot regions. It would prompt local governments to take strategic measures to reduce carbon emissions.

As stated in the Notice on Carbon Emission Trading Pilot Work, the central government formulated this policy with the objective of utilizing market mechanisms to achieve the 2020 action goal of greenhouse gas emissions control at a lower cost. Additionally, the document emphasizes the acceleration of economic development mode transformation and industrial structure upgrading. This underscores the central government's profound consideration for the potential implications of CETS on both the economy and the environment. In other words, the central government's intention is for CETS to affect carbon emission reductions while simultaneously contributing to the economy or, at the very least, avoiding adverse impacts on the economy.

3.2. Institutional background

Generally speaking, policies designated by the central government need to be implemented by local governments. And the effectiveness of policy implementation often depends on the features of the allocation of authority and accountability in government hierarchies. When it comes to the distribution of intergovernmental authority, neither federalism nor extreme centralism can accurately illustrate the reality in China [46]. China's administrative system can be viewed from the following two perspectives. On the one hand, in terms of decentralization, the central government frequently merely chooses a broad direction for policy and then allows local governments to be in charge of putting the policy into practice based on the real situation. This indicates that local administrations have some latitude in implementing policies. However, this discretion may go beyond what the central government wants because of information asymmetries. On the other hand, in terms of centralization, officials' chances of promotion under China's hierarchical system are heavily reliant on their superiors. This means that in response to various decisions made by the central government, local governments must have a constructive attitude and take appropriate action.

When China wants to conduct a policy experiment, this hierarchical pattern of experimentation is rooted in unique foundations that differ from concepts such as decentralization or federalism [47]. Although local officials are entrusted with the execution of pilot policies, the overarching authority of the central government prevents local administrations from taking a lax approach. In their quest to demonstrate political performance to the central government, some local officials might exert considerable efforts to ensure the success of the pilot policy, thereby rendering the experiment atypical and challenging to replicate [25]. In practice, within the framework of policy experimentation under hierarchical governance, China's CETS pilot constitutes a complex interactive game involving multiple entities - the central government, local governments, and emission enterprises. In this intricate scenario, the central government assumes the role of devising environmental regulations, local governments recalibrate their action strategies based on the evolving preferences of the central government, and firms adapt their production practices in accordance with the local policy context and enforcement endeavors.

3.3. Research hypotheses

3.3.1. Market incentives

In theory, utilizing market forces to control total carbon emissions can address the inefficiencies in the initial allocation of carbon emissions, unlock substantial potential for energy conservation and emission reduction, and create a mutually beneficial scenario for environmental preservation and economic advancement [3–5]. In practical terms, when the central government opts to implement the CETS within a region, that region is required to establish a comprehensive carbon emission target, considering economic growth and carbon reduction objectives. Subsequently, this target is apportioned among the regional enterprises. Given the tradable nature of emission allowances, entities with lower emission levels stand to gain from carbon reduction, while those exceeding their allowances face emission-related costs. As a system designed to harness market incentives, the effectiveness of CETS in reducing emissions hinges on the degree of perfection in the market mechanism or its operational efficiency [9]. Consequently, a well-structured and developed carbon trading market is more likely to attain heightened carbon emission reductions within a given economic scope, thus realizing a symbiotic outcome of sustaining economic growth while reining in carbon emissions. In light of the above analysis, the following hypothesis is proposed.

H1. The market mechanism of the carbon market can promote the emission reduction effect of China's CETS.

3.3.2. Political incentives

(1) Political incentives embodied in political statements

The findings of previous studies demonstrated that the market mechanism does contribute to emission reduction, and it is impossible to ignore the influence of non-market elements. Even though there are different evaluation measures for government intervention, the relevant studies demonstrated that government intervention is essential to the CETS pilot's ability to reduce emissions [19,20]. According to Lin and Huang [19], local governments would use their administrative power to compel businesses to put pressure on companies to reduce carbon emissions. Since they are under intense pressure from the central government and the general public to minimize pollution. However, the essential question is whether there are any appreciable distinctions between pilot zones and non-pilot regions in terms of the pressures placed on reducing emissions. We believe that, in a hierarchical administrative system such as China's, where the central government has absolute authority, the the central government and the general public should pay more attention to an area if it earns the pilot qualification. Evidently, this extra attention will inevitably have an impact on the observed object, which is called the Hawthorne effect.

As a central government-led environmental regulation strategy, CETS has amply illustrated to local governments the central government's unwavering determination to taking action to reduce carbon emissions. There is no justification for municipal governments not to demonstrate their allegiance. However, the central government opposes "campaign-style" carbon reduction that harms the economy.[2] Only if the "pilot program" lowers carbon dioxide emissions while maintaining steady economic growth can it be deemed a successful policy experiment. This leads us to propose the hypothesis that follows.

H2-1: Responding to the central government's expectation of a "win-win" situation for the environment and the economy, the CETS pilot will incentivize local governments to emphasize the importance of both environmental and economic objectives in their political statements to show loyalty to higher levels of government.

[2] On July 30, 2021, the Political Bureau of the CPC Central Committee proposed to rectify "campaign-style" carbon reduction. Since then, Chinese officials have repeatedly emphasized that local governments should avoid setting overly ambitious and unrealistic goals or simply chanted slogans without taking actions in carbon emission reduction actions.

(2) Political incentives embodied in practical action

The analysis of the Hawthorne effect in Hypothesis H2-1 takes into account only the political statements of local governments, but not their actual actions. Unlike political statements, the actual actions of local governments are constrained by many practical factors and legal frameworks. Therefore, high-profile policy statements do not always translate into strict implementation. More fundamentally, whether local governments will actually strictly control carbon emissions in practice depends on whether they will devote more administrative resources to the task.

In reality, local governments face the constraints of multi-tasking. In general, local governments will allocate administrative resources in accordance with the maximization of local interests under the multi-objective constraint. However, under a hierarchical administrative system in which the central government has authority, local officials who want to be promoted must work on the basis of the central government's preferences. Therefore, local governments will devote more administrative resources to measures that promote economic growth and disregard the regulation of environmental degradation when the central government sets a high priority on GDP targets [48]. Of course, the preferences of the central government are not static. Since socialism with Chinese characteristics has entered a "new era", the central government is more concerned than ever about environmental protection [49]. In this regard, the "GDP-only" development mindset of the past is being withdrawn from the stage of history. Therefore, local governments must place environmental protection in a more important position in their own target management.

It is crucial to emphasize that this does not imply that the goal of economic growth is no longer significant. For carbon emissions, emission rights are the right to development, which is crucial for a developing nation that is only now coming into a society that is fairly rich. A major slowdown in economic development may result from severe carbon reduction regulations, at least until China hits its "peak carbon" target. The central government does not want to see the shortsighted actions that local governments disregarded economic growth in order to meet carbon reduction goals.

Faced with this dilemma - to achieve economic growth while achieving low carbon emissions, what will local governments do? Looking at the economic growth statistics for China's cities, as shown in Fig. 2, prior to 2012, the majority of cities, whether or not they were a member of a pilot region, were able to achieve their economic growth goals. Few cities achieved their economic growth goals after 2012. In addition, we discovered that, since 2014, the proportion of cities fulfilling their growth targets in the pilot areas has been much lower than in the non-pilot areas. It means that China's CETS may have inhibited the motivation of local governments in the pilot areas to achieve their economic growth targets. Therefore, we propose the following hypothesis.

H2-2: In terms of actual behavior rather than political statement, China's CETS policy pilot will increase local governments' efforts to solve ecological and environmental concerns like carbon emissions, and slightly diminish their efforts to economic growth goals.

In sum, as a policy experiment conducted under a hierarchical administration and centralized political system, China's CETS pilot policy is bound to create additional policy incentives for its subjects (i.e., the local governments in the pilot areas) in practice. As shown in Fig. 3, these incentives will be reflected in the policy statements and practical actions taken by local governments to achieve various governance goals. Here we show only the economic and environmental aspects, which are the most important for local governments and relevant for this paper.

4. Materials & methods

4.1. Research design

China's CETS was introduced incrementally through a phased "pilot" manner, akin to a quasi-natural experiment. In this context, cities within the pilot area form the treated group, while other cities serve as the control group. There are two ideas about the initial timing of the policy shock in the existing research. Some writings refer to 2011 as the policy implementation node because that is the year the NDRC released the list of pilot cities [32,50]. Other studies refer to 2013 or 2014 as the node because the carbon trading markets are launched one after another in these two years [19,29]. We chose the time of policy announcement as the policy initiation point because this study examines the political incentives for the pilot policy. Based on the analysis in this paper, we argue that political incentives emerge after the central government approves the CETS pilot. Specifically, the policy node for official pilot regions such as Beijing is 2011, and the policy node for Fujian and Sichuan provinces is 2016.

By comparing the differences between the control and treatment groups before to and following the implementation of the CETS pilot, it is possible to estimate the impact of policy implementation. This approach, also referred to as the difference-in-differences (DID) method, is frequently used to assess the effects of policy shock [15, 29, 30, 32]. Due to the treatment group sample's inconsistent policy nodes, the multi-period DID model was used. Before implementing a policy, DID additionally mandates that the treatment and control groups concur with the parallel trend assumption [51,52]. Regarding the first issue, China's CETS is a policy that is piloted at the province level and is guided by the central government. And the focus of this study is on prefecture-level municipalities, which did not have the ability to influence the central government's choice of pilot areas. As a result, the selection of the treatment group can be regarded as compliant. In regards to the second issue, we can apply a parallel trend test to see if the requirements are fulfilled.

4.2. Model setting

4.2.1. Assessment of carbon reduction effects

In order to assess and test the carbon emission reduction effect of the carbon market, we develop a benchmark regression model as

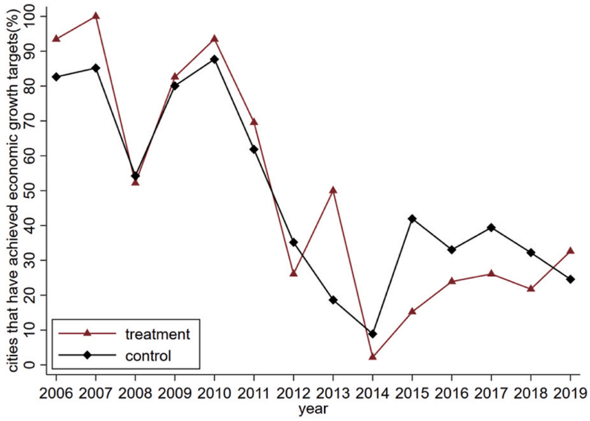

Fig. 2. Percentage of prefecture level cities which achieved its economic growth.

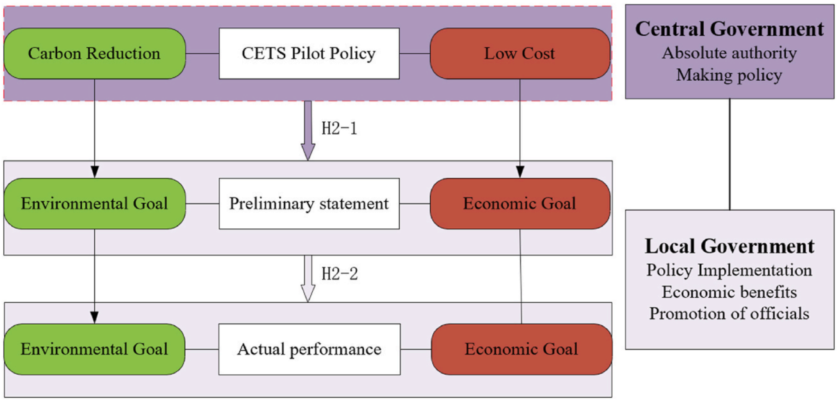

Fig. 3. The political incentive effect of China's CETS pilot policy.

follows

$$CE_{it} = \alpha_0 + \alpha DID_{it} + \theta X_{it} + \gamma_p + u_i + \lambda_t + \delta_{rt} + \epsilon_{it} \tag{1}$$

In formula (1), α、 θ are parameters to be estimated; subscripts i denotes city and t denotes year; CE_{it} represents carbon emissions; dummy variable $DID_{it} = treat_i \times post_t$ denotes policy impact; X_{it} represents a series of control variables that affect carbon emissions; γ_p denotes province fixed effect; u_i denotes individual fixed effect; λ_t denotes year fixed effect; δ_{rt} captures the region-year interaction effect[3]; ϵ_{it} denotes random error.

4.2.2. Impact assessment of market incentives

Based on the analysis in Section 3.3.1, we need to test whether the level of market development affects the emission reduction effect of CETS, and estimate the magnitude of the impact. For this purpose, equation (1) is extended to the following form

$$CE_{it} = \alpha_0 + \alpha DID_{it} + \rho DID_{it} \times Level_{it} + \theta X_{it} + \gamma_p + u_i + \lambda_t + \delta_{rt} + \epsilon_{it} \tag{2}$$

In formula (2), $Level_{it}$ represents the development level of carbon emission market. Since $DID_{it} \times Level_{it} = Level_{it}$, it is not necessary to introduce $Level_{it}$ into formula (2). At this point, the coefficient ρ reveals the policy effect under market incentives.

4.2.3. Assessment of political incentive effects

Based on assumptions H2-1 and H2-2, we expect that CETS pilot will cause Hawthorne effect. Essentially, this effect stems from political incentives. In order to verify the above hypotheses, the following DID model is set in this paper.

[3] The website of the Chinese Ministry of Civil Affairs publishes the codes for administrative regions above the county level, and according to the first digit of this code, we can divide mainland China into six regions.

$$GovAct_{it} = \beta_0 + \beta DID_{it} + \varphi X_{it}^{'} + \gamma_p + u_i + \lambda_t + \delta_{rt} + \epsilon_{it} \quad (3)$$

In equation (3), β、 φ are parameters to be estimated; $GovAct_{it}$ represents the impact of pilot status on local government behavior (advance statement and actual performance); $X_{it}^{'}$ represents a series of control variables; other parameters have the same meanings in formula (1).

4.3. Variables

4.3.1. Carbon emissions

In the empirical analysis, we choose total carbon emissions and carbon intensity (i.e., carbon emissions per unit of GDP) as the explained variables. The measurement methods of city's carbon emissions are introduced as follows.

The website of CEADs provides three types of emission inventories at provincial, city and county levels. The carbon emissions of provinces and cities are mainly calculated based on 17 fossil fuels used by 47 social and economic sectors, and the carbon emissions in the cement production process are also considered [53,54]. Due to the poor availability of data at city level, the energy consumptions of cities can only be estimated by downscaling provincial data based on socioeconomic indexes. Obviously, this method leads to increased data uncertainty [54]. The county-level carbon emission data is the fitting value by downscaling the provincial energy-carbon emissions based on the nighttime light data [28]. Taken together, the provincial and county-level data of CEADs are more credible. Therefore, referring to the idea of Wu et al. (2021), this paper sums up the county-level carbon emission data of CEADs to the city level as a measure of urban carbon emissions.

Since the county-level carbon emission inventory of CEADs is currently updated only to 2017, while the sample of this paper is up to 2019. For this reason, we use regression fitting method to interpolate the municipal carbon emissions for 2018 and 2019. First, we calculated the proportion of the city's carbon emissions, GDP, population and secondary industry output in the province; Secondly, we made linear regression fitting for the above variables based on the samples from 2006 to 2017. Further, we put the data of 2018 and 2019 into the fitting equation to estimate the proportion of city's carbon emissions in the province.[4] Finally, based on this proportion, we can then downscale the provincial carbon emission data to the city level.

4.3.2. Mechanism variables

Market incentive variables. In this paper, we use carbon trading price (*did_price*), carbon market activity (*did_active*) and scale (*did_scale*) to measure the development level of carbon trading market. All these data come from the Carbon Trading Network. Specifically, the measurement method of each indicator is as follows. (1) *did_price* is the average annual price of carbon trading; (2) *did_active* is the number of trading days in the year; (3) *did_scale* is the proportion of total annual trading volume to carbon emissions in the province. It should be pointed out that the carbon trading market was established at the provincial level (except for Shenzhen city), and the above indicators may not accurately measure the impact of market development level on urban carbon emissions. Therefore, this paper takes the proportion of carbon emissions of cities in their provinces as the weight and weights each index.

Political incentive variables. The frequency of pertinent words in the government work report, as the reflection of political statements can be used to demonstrate the local government's attention to a particular aim (Chen et al., 2018). However, there may be a significant mistake present if the local government's attention to the target is simply inferred from the percentage of a particular target entry in the overall text. The cause is due to the fact that different geographical areas and report drafters have various modes of expression. Even if we were to precisely count the target terms' occurrence times (as the numerator), systematic mistakes in the overall number of terms in the report (as the denominator) would prevent us from comparing accurately measurement findings across regions. In order to avoid the aforementioned issues, we chose the three most crucial government multi-task management goals—the ecological environment, economic development, and public service—counted the times at which each entry related to the goal occurred in turn in the government work report, and then combined those times as the denominator. We employ $Atten\_env_{it}$ and $Atten\_eco_{it}$ to reflect the political statements of the local governments toward pertinent targets.

We also need to evaluate how the pilot program affected local governments' actual efforts to reach the relevant goals. Since the Chinese government typically views "carbon reduction" and "pollution reduction" as related goals, we uses regional PM2.5 to examine the real effects of the pilot policy's political incentives on environmental goals. This study chooses the regional real economic growth ($GDPgrow_{it}$), the degree of top-down amplification of economic growth targets ($GrowAmp_{it}$), and Unplanned-Growth ($EcoPerf_{it}$)[5]to measure the actual performance of local governments in relation to economic growth targets. The variable $EcoPerf_{it}$ indicates the actual regional economic growth rate less the current year's economic growth target, while the variable $GrowAmp_{it}$ reflects the city's economic growth target less the provincial economic growth target.

[4] We used two regressions fitted by OLS method with the share of city's carbon emissions as the dependent variable. One is a direct regression for the full sample, and the other is a regression by province. Then, for each city, we choose the regression with the highest fitting degree (i.e., R^2 is greater) to predict the results.

[5] The local government's pursuit of economic growth can be broken down into two categories: economic growth target and *unplanned economic growth* (Zhan and Liu, 2020). The economic growth target that are explicitly announced in government work reports usually lead to receive more attention from superiors and the public, whereas the unplanned economic growth does not face such constraints. As a result, reducing the efforts for unplanned economic growth is easier to achieve when local governments are under increased pressure to protect the environment.

4.3.3. Control variables

In the benchmark model and market incentive test model, i.e. Formula (1) & (2), we select the following control variables that may affect regional carbon emissions: (1) Economic development level, represented by GDP per capita (*lnPerGDP*) and GDP per unit area (*GDP_Area*); (2) Industrial structure, represented by the proportion of secondary industry (*y2rate*); (3) Population density (*popDen*); (4) Proportion of foreign investment in GDP (*FdiRate*); (5) The ratio of research expenditure to GDP (*Science_inv*); (6) The proportion of industrial electricity consumption in total electricity consumption (*IndElcStr*); (7) Macro tax (*MacTax*), which is measured by the ratio of general budget revenue to GDP.

In the political incentive test model, i.e. Formula (3), when the dependent variable is the government's attention and economic growth target, which have strong subjective anticipation rather than the result index, the lag period of the control variable in formula (1) and (2) is taken as the control variable of formula (3). When the dependent variables are objective outcome indicators such as *EcoPerf* and *GDPgrow*, the following variables are controlled by referring to the method of Zhan and Liu [55] and combining with the research purpose of this paper: (1) Human capital (*hc*), which can be measured by the number of college students per 10,000; (2) The sum of population growth rate, technological progress rate and capital depreciation rate (*ngderta*)[6]; (3) Regional macro tax burden (*MacTax*); (4) Provincial marketization level (*market_pr*).

4.4. Samples and data

China first set out its energy saving and emission reduction targets in its 11th Five-Year Plan, so we set the starting year of the sample at 2006 (the start of the 11th Five-Year Plan). Due to data availability and timeliness, we have taken 2019 as the end year of our sample. The CETS pilot in China was launched at the provincial level. The central government finally approved seven pilots based on the declaration and actual situation of each region. If the provinces are used as the subject, there may be problems of sample self-selection. Therefore, we use cities as the object of analysis in this study. Based on the availability of data, we used 283 cities as the study sample. The relevant data used in the empirical analysis were obtained from the Carbon Emissions Accounts & Datasets (CEADs), the Carbon Trading Network (http://www.tanjiaoyi.com), the China City Statistical Yearbook, and government work reports. We use balanced panel data for regression, and some data have a few missing values, which are filled in by linear interpolation. Definitions and descriptive statistics of the variables are shown in Table 1.

5. Results and robustness tests

5.1. Carbon emission reduction effect of China's CETS pilot

Table 2 displays the benchmark regression results in accordance with the set model (1). Based on the regression results, in the pilot area, the CETS policy reduced intensity by 13.26% and total carbon emissions by 13.35% (as shown in columns V and VI), respectively. This result is generally consistent with existing studies [10–13,16]. This implies that China's CETS policy indeed contributes to carbon emissions reduction. Nevertheless, there is a need for further exploration to ascertain the precise mechanisms underlying this reduction effect.

5.2. Parallel trend and dynamic effect test

The DID method requires the treatment group and the control group to meet the standard of the parallel trend hypothesis. The sample interval selected in this paper is from 2006 to 2019, and 64 cities belong to the treatment group, among which 37 cities' policy impact occurred in 2011. Therefore, we take the five years before the policy as the base period to conduct a parallel trend test. The model setting is shown in Formula (4). The total amount and intensity of carbon emissions were respectively substituted into Equation (4) as explained variables, and the test results as shown in Fig. 4 below (In Fig. 4 (a), the test results are described with carbon emission intensity (lnCO2gdp) as the dependent variable, while Fig. 4 (b) presents the results with total carbon emissions (lnCO2) as the dependent variable.). It can be seen from the test results that the treatment group and the control group before policy occurrence meet the parallel trend, so the baseline regression results are credible.

$$CE_{it} = \alpha_0 + \sum_{k=-4}^{8} \alpha_k DID_{ik} + \theta X_{it} + \gamma_p + u_i + \lambda_t + \delta_{rt} + \epsilon_{it} \tag{4}$$

As can be seen in Fig. 4, the pilot list had an abatement effect in the year it was released. This result echoes the findings of other studies that found that China's CET S was accompanied by expected effects of the policy [12,20,42,43]. The carbon market was not yet officially operational within one to two years after the pilot list was released. Therefore, this abatement effect may result both from emitters' expectations of the carbon market launch and from the political incentives received by local governments.

From the perspective of dynamic effect, the emission reduction effect basically increases year by year, but the absolute value of the coefficient decreases after the seventh year. The possible reason is that the pilot areas received special attention from the central

[6] In most studies, the capital depreciation rate is set as 0.05, which is followed in this paper. The rate of technological progress is calculated based on the Malmquist-Luenberger method.

Table 1
Summary statistics.

Variables	Definitions	Obs	Mean	SD	Min	Max
lnCO2	Total CO_2 emissions (in log)	3962	3.04	0.80	0.61	5.51
lnCO2gdp	CO_2 emissions per unit of GDP (in log)	3962	0.73	0.61	−1.61	3.24
lnPerGDP	GDP per capita (in log)	3962	10.26	0.70	7.92	12.36
GDP_Area	GDP per unit area	3962	0.22	0.52	0.00	10.04
y2rate	Proportion of secondary industry	3962	47.78	10.92	11.70	90.97
popDen	Population density	3962	0.47	0.53	0.01	6.73
FdiRate	Share of foreign investment in GDP	3962	1.90	2.95	0.00	90.51
Science_inv	Share of scientific expenditure in GDP	3962	0.23	0.24	0.00	6.31
IndElcStr	Proportion of industrial electricity	3962	65.03	17.82	0.52	97.55
MacTax	Share of fiscal revenue in GDP	3962	7.15	2.86	0.53	25.70
did_scale	Transaction scale of carbon market	3962	0.01	0.08	0.00	1.86
did_active	Carbon market activity	3962	0.03	0.15	0.00	1.87
did_price	Average annual price of CO_2 trading	3962	0.00	0.01	0.00	0.28
Atten_env	Government's attention to the environmental protection	3662	33.75	6.86	10.05	83.47
Atten_eco	Attention to the economic growth	3662	19.50	5.13	8.18	80.00
EcoPerf	Unplanned-Growth	3962	−0.26	2.72	−22.00	15.10
GDPgrow	growth rate of real GDP	3962	10.60	4.17	−14.00	32.90
GrowAmp	Top-down Amplification of Growth Targets	3962	1.62	2.03	−7.10	20.70

Table 2
Carbon emission reduction effect of China's CETS pilot.

	(1)	(2)	(3)	(4)	(5)	(6)
	lnCO2gdp	lnCO2	lnCO2gdp	lnCO2	lnCO2gdp	lnCO2
DIDset	−0.1715***	−0.1315***	−0.1122**	−0.1136**	−0.1326***	−0.1335***
	(-4.16)	(-3.21)	(-2.63)	(-2.34)	(-3.12)	(-3.27)
_cons	0.7458***	3.0544***	0.7392***	3.0524***	4.8848***	2.7667**
	(162.67)	(670.03)	(155.65)	(565.96)	(3.76)	(2.29)
Control variables	No	No	No	No	Yes	Yes
ID/Year	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Province	No	No	Yes	Yes	Yes	Yes
Region × year	No	No	Yes	Yes	Yes	Yes
N	3962	3962	3962	3962	3962	3962
R2	0.9119	0.9520	0.9373	0.9645	0.9408	0.9666

Robust t-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Standard errors are clustered to province.

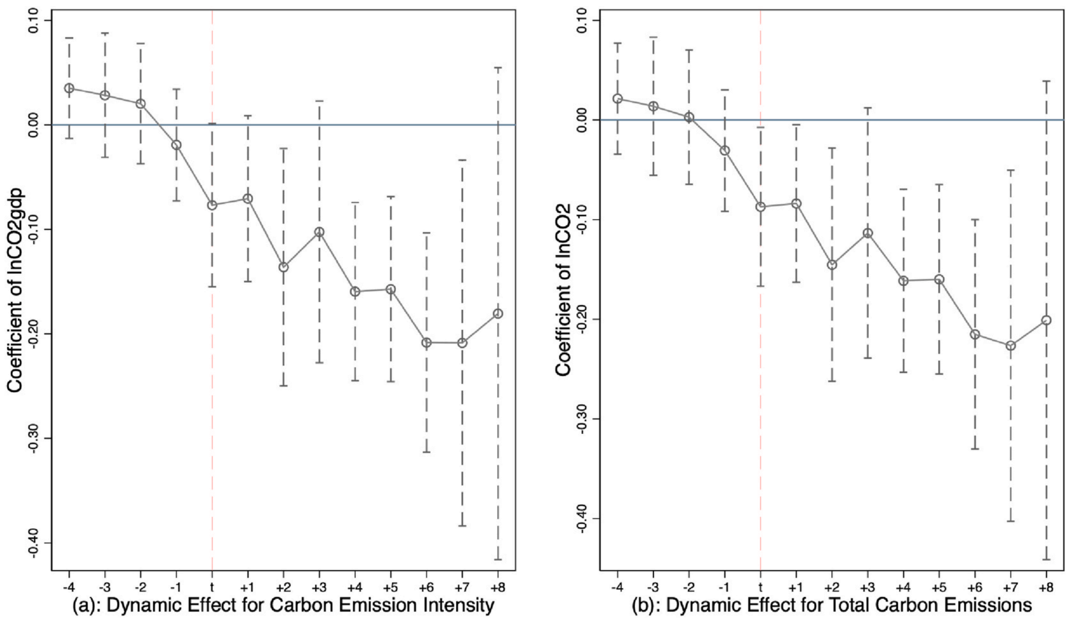

Fig. 4. Parallel trend and dynamic effect test.

government at the early stage of the policy implementation, and the carbon market was operating more and more stably, so the emission reduction effect showed a trend of increasing yearly. As time goes on, and the central government begins to gradually launch a national carbon trading market,[7] the focus on pilot areas may diminish. As a result, the political incentives for local governments in pilot areas are no longer so different from those in non-pilot areas.

5.3. Robustness tests

5.3.1. The placebo test

The basic idea of the placebo test is to test the robustness of the original estimate by constructing false policy shocks. The steps of placebo test for the multi-phase DID model are as follows: First, we randomly selected 8 provincial administrative regions from the samples between 2007 and 2018 as the "pseudo-treatment group"; Second, each "pseudo-processing group" was randomly assigned the year the policy was started. Finally, based on formula (1), it is tested whether the impact of this "pseudo policy" is significant. The above process was repeated 500 times to obtain the estimated coefficients of 500 "pseudo policies". If the coefficients of DID in Table 2 (−0.1375 and −0.1360) were at the low tail of the "pseudo policy" estimation coefficient distribution, the baseline regression results are considered to pass the placebo test. The results of placebo test were shown in Fig. 5 below (In Fig. 5 (a), the test results are described with carbon emission intensity (ln CO2gdp) as the dependent variable, while Fig. 5 (b) presents the results with total carbon emissions (ln CO2) as the dependent variable.).

As observed, only a limited number of coefficients are to the left of the baseline results after treatment group randomization and policy start date. Realistically, the Chinese government's mandate to include the national power generation sector in the carbon trading market by the end of 2017 could potentially influence a reduction effect in certain non-pilot provinces characterized by a significant share of power generation. To account for this, we re-randomized the sample to exclude data points beyond 2018, at which point the results of all coefficients in the placebo test appear to the right of the baseline results. In conclusion, the results show that the baseline regression results of this paper are robust, and the CETS pilot does reduce the carbon emission in the pilot area.

5.3.2. PSM-DID

Propensity scores matched difference (PSM-DID) method can better avoid the estimation error caused by sample selection bias, and we use this method to conduct further robustness test. Since the pilot policy was launched in 2011, we take the control variable in the benchmark model as the covariable. The specific steps are as follows: First, the samples from 2006 to 2010 were matched with year-by-year propensity scores, and the samples satisfying the common area hypothesis in each year were retained. Then, the benchmark model is estimated based on the above samples. We adopt three methods of kernel matching, radius matching and nearest neighbor matching were adopted to match propensity scores, and the regression results shown in Table 3 were obtained. As can be seen from Table 3, no matter which matching method is adopted, the coefficient of *DIDset* is negative at the significance level of 1%, and the coefficient is close to the benchmark model. Therefore, it can be considered that the estimated results of the benchmark model are robust, and the emission reduction effects of China's CETS are significant.

5.3.3. Removing special samples

This study makes the case that the political incentives produced by local governments realizing they are the test subjects contribute to the emission reduction effect of China's CETS pilot. Therefore, it's possible that the inclusion of Sichuan and Fujian-the provinces that have willingly joined the CETS pilot-in the treatment group underestimated this political incentive. Additionally, the higher political standing of provincial capitals, sub-provincial cities, and municipalities directly under the central government may both draw specialized attention from the central government (thereby enhancing the incentive effect of the pilot policy) and provide them with greater autonomy in carrying out the central government policy (thus reducing the incentive effect of the pilot policy). In either case, this might skew our estimates of the effects of the policies.

After deleting these exceptional samples, the baseline model is re-estimated based on the analyses mentioned above. In Table 4, columns 1 and 2 display the estimation results after the Sichuan and Fujian samples have been eliminated, whereas columns 3 and 4 display the estimation results after the sub-provincial cities have been eliminated. As can be observed, CETS continues to have a considerable impact on emissions, and the results of the baseline regression remain solid. We observe that when excluding the voluntary pilot districts, the absolute values of the DID coefficients increase in comparison to the baseline regression results in Table 2 (−0.1326 for lnCO2gdp and −0.1335 for lnCO2). Conversely, after removing the sub-provincial cities, the absolute values of the coefficients decrease. Broadly, voluntary pilot regions tend to receive less attention from higher-level authorities compared to official pilot regions. Conversely, regions with higher administrative levels are more likely to attract greater attention from superiors. It means that the abatement effect of CETS is not entirely a function of market mechanisms, but rather the presence of political incentives, is somewhat supported by the findings.

5.3.4. Shortening of the sample time window

After 2017, the central government began nationwide carbon emissions trading in the power generation sector, which may have caused bias in the estimation of the baseline regression. In addition, the urban carbon emission data for 2018 and 2019 were obtained

[7] At the end of 2017, China took the power generation industry as a breakthrough to prepare for the launch of a nationwide carbon trading market. After nearly four years of preparation, the national carbon market was officially launched on July 16, 2021.

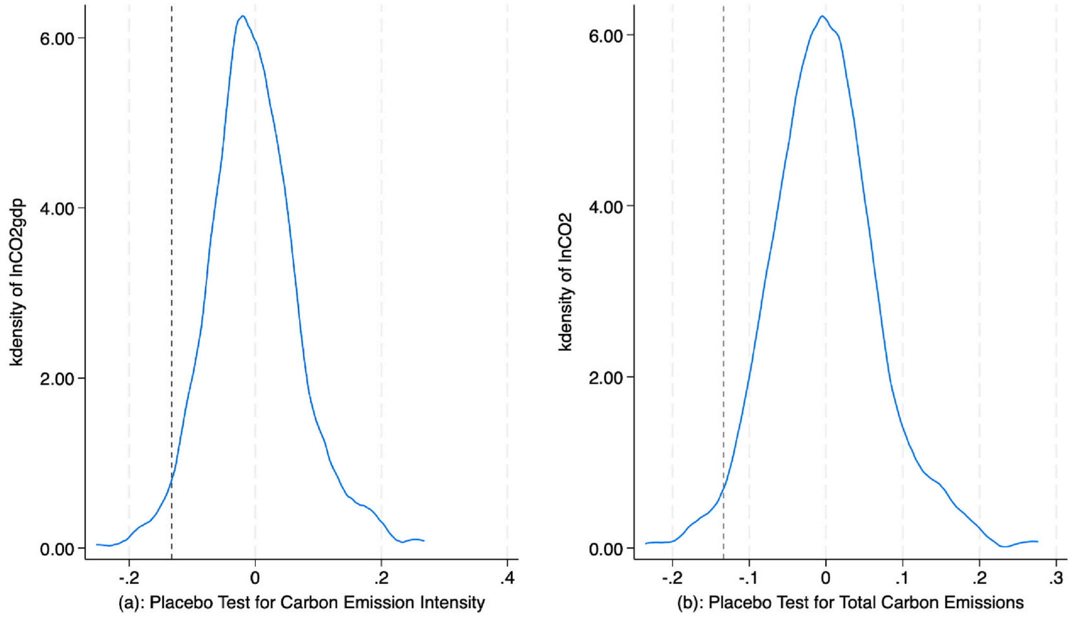

Fig. 5. Placebo test based on pseudo-policy shocks.

Table 3
Estimation results of PSM-DID.

	(1)	(2)	(3)	(4)	(5)	(6)
	Kernel		radius		Neighbor	
	lnCO2gdp	lnCO2	lnCO2gdp	lnCO2	lnCO2gdp	lnCO2
DIDset	−0.1153***	−0.1040***	−0.1146***	−0.1034***	−0.1261***	−0.1165***
	(-3.17)	(-2.87)	(-3.15)	(-2.85)	(-3.37)	(-3.11)
_cons	2.9852**	1.5123	2.9150**	1.4242	3.2614***	1.8409
	(2.73)	(1.15)	(2.69)	(1.05)	(3.07)	(1.33)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
ID/Year	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
Region × year	Yes	Yes	Yes	Yes	Yes	Yes
N	2912	2912	2884	2884	2982	2982
R2	0.9365	0.9716	0.9361	0.9712	0.9360	0.9718

Robust t-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Standard errors are clustered to province.

Table 4
Regression results after removing special samples.

	(1)	(2)	(3)	(4)
	Delete voluntary pilot areas		Delete sub-provincial cities	
	lnCO2gdp	lnCO2	lnCO2gdp	lnCO2
DIDset	−0.2142***	−0.2009***	−0.1149***	−0.1149***
	(-5.30)	(-4.57)	(-3.03)	(-3.23)
_cons	5.2940***	3.0868**	5.2777***	2.8388**
	(3.92)	(2.48)	(3.45)	(2.60)
Control variables	Yes	Yes	Yes	Yes
ID/Year	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Province	Yes	Yes	Yes	Yes
Region × year	Yes	Yes	Yes	Yes
N	3584	3584	3472	3472
R2	0.9416	0.9664	0.9393	0.9628

Robust t-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Standard errors are clustered to province.

after downscaling the provincial carbon emissions by fitting a linear regression, which may also lead to errors in the estimation results. Therefore, this paper only regresses the samples between 2006 and 2017 to test the robustness of the baseline model. The regression results are shown in columns (1) and (2) of Table 5. This result indicates that CETS has a significant emission reduction effect and the baseline regression results are robust.

5.3.5. Set DID in accordance with the actual start time of the carbon market

Moreover, as mentioned above, the actual start of the carbon market in the official pilot regions was in 2013 and 2014, not in 2011 when the pilot list was published. Therefore, we re-estimate the baseline model with the onset of the policy shock set to the actual start of the carbon market. The new estimation results are shown in columns (3) and (4) of Table 5. We see that the coefficients of the policy shocks are still significantly negative and very close to the baseline results. This implies that the conclusions of this paper are indeed robust.

5.3.6. Excluding the interference of competitive policies

In addition to CETS, China has also implemented pilot low-carbon cities, pilot emission trading schemes and the 12th Five-Year Plan for air pollution prevention and control in key areas within the sample area. The implementation of these policies may also have a certain impact on regional carbon emissions, resulting in the error of the estimated results in this paper. To this end, we use the policy dummy variables *DIDlc*, *DIDso2*, and *DIDcity47* to control the impact of the above policies. After introducing the above three policy dummy variables into the benchmark model, the estimated results are obtained as shown in columns (5) and (6) of Table 5. The results show that after the introduction of competitive policies, the absolute value of the estimated coefficient of CETS pilot in the benchmark model only slightly decreases and still passes the 1% significance test. This indicates that the benchmark regression results are very robust.

5.3.7. Heterogeneous robust estimation of staggered DID

An important consideration when employing the staggered DID approach is the existence of heterogeneous treatment effects, which can introduce potential bias in both static and dynamic estimations when utilizing the traditional Two-Way Fixed Effects Model Estimator (TWFE) [56]. In the static context, as emphasized by Goodman-Bacon (2021), the TWFE method is susceptible to what is known as the “bad control group” problem. Even when the “trend in parallelism” assumption is met, differences in treatment timing may result in samples treated earlier serving as the control group for samples treated later, potentially leading to estimation bias. To address this issue, we refer Goodman-Bacon (2021) for additional robustness checks of the benchmark results. As shown in Table 6, the influence of the “bad treatment group” (Late Vs. Early) is only 3%, which means that the bias in the estimates obtained from the benchmark regression is small. To mitigate the risk of employing a “bad control group” (i.e., individuals exposed to policy shocks earlier) as a reference, Callaway and Sant’Anna (2021) advocate for computing group-period average treatment effects [57]. This approach is adopted in this paper to ensure a robust assessment of heterogeneity. The outcomes of these calculations align closely with those derived from the baseline regressions, reinforcing the robustness of the results obtained in this study.

Table 5
Results of other robustness tests.

	(1)	(2)	(3)	(4)	(5)	(6)
	Delete samples after 2018		Actual start time		Controlling other policies	
	lnCO2gdp	lnCO2	lnCO2gdp	lnCO2	lnCO2gdp	lnCO2
DIDset	−0.1261***	−0.1219***	−0.1162***	−0.1185***	−0.1124***	−0.1195***
	(-3.42)	(-3.45)	(-3.09)	(-3.28)	(-2.98)	(-3.06)
DIDlc					−0.0305	−0.0171
					(-1.29)	(-0.70)
DIDso2					−0.0046	−0.0141
					(-0.15)	(-0.42)
DIDcity47					−0.0796***	−0.0686**
					(-2.86)	(-2.58)
_cons	4.1514***	2.2387***	4.8967***	2.7792**	5.2082***	3.0339**
	(3.12)	(3.08)	(3.73)	(2.30)	(3.74)	(2.75)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
ID/Year	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
Region × year	Yes	Yes	Yes	Yes	Yes	Yes
N	3396	3396	3962	3962	3962	3962
R2	0.9864	0.9939	0.9405	0.9665	0.9414	0.9669

Robust t-statistics in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Standard errors are clustered to province.

Table 6
Bacon breakdown results and heterogeneous robust estimation.

Category	Weights		Average DID estimate	
	lnCO2gdp	lnCO2	lnCO2gdp	lnCO2
Early_v_Late	0.0387	0.0387	−0.0553	−0.0970
Late_v_Early	0.0309	0.0309	0.0158	0.0451
Never_v_Timing	0.9304	0.9304	−0.1825	−0.1388
Heterogeneous robust estimation by Callaway and Sant'Anna (2021)			−0.1244*** (−3.32)	−0.1308*** (−4.29)

6. Discussion on carbon reduction mechanisms

6.1. Carbon reduction with market incentives

We utilize Equation (2) from Section 4.2.2 to approximate the influence of market incentives on emission reductions. Even though the percentage of non-zero trading days and trading prices may not be the optimal measures to portray the advancement of carbon markets, we use these indicators and transaction size as moderating variables to assess how the extent of market development affects the impact of emission reductions. This approach is taken to facilitate comparison with previous research. Table 7 presents our estimation findings.

Overall, columns (1) and (4) are in line with Wu et al.'s empirical outcomes [20], revealing that a greater degree of market development bolsters the effectiveness of carbon trading policies in curbing emissions. As anticipated, this result confirms Hypothesis 1. It is important to note that the results in Table 7 differ from the empirical results of Wu et al. [20] and Lin and Huang [19]. We find that the percentage of non-zero trading days and the price of carbon trading do not have a significant impact on the reduction of emissions through the carbon market. This aligns with our previous view that these two indicators are not ideal for characterizing the development of the carbon market. Taken together, this paper concludes that the inhibiting effect of China's CETS on carbon emissions is not solely attributed to the market mechanism.

In addition, Table 7's columns (1) and (4) suggest that the pilot policy can still reduce emissions with a very small market - the DID coefficients are −0.1166 and −0.1182, respectively. It is probable that the decrease in emissions is due to factors other than the market mechanism.

6.2. How pilot policies affect local officials' political motivations

Using equation (3) in Section 4.2.3, we estimate the political incentive effects from the pilot policies to test hypotheses H2-1 and H2-2. Given that other policy pilots may also be accompanied by matching political incentives as already noted in Section 5.3.5 of this paper, this paper controls for these competing policies in the parameter estimates. At the same time, given that a region's level of economic development in the current year occurs in time after the local government's political statements and actual actions, to avoid the problem of reverse causality, in the regression estimation here we introduce the control variables from the benchmark regression into the model one period lagged. The estimation results and discussion follow.

6.2.1. Political statement of local government

Table 8 shows the regression results of China's CETS pilot policy on local governments' political statements. The results show that

Table 7
Carbon reduction with market incentives.

	(1)	(2)	(3)	(4)	(5)	(6)
	lnCO2gdp	lnCO2gdp	lnCO2gdp	lnCO2	lnCO2	lnCO2
DIDset	−0.1166**	−0.1331***	−0.1341***	−0.1182***	−0.1363***	−0.1370***
	(-2.73)	(-3.19)	(-3.15)	(-2.93)	(-3.53)	(-3.40)
did_scale	−0.1511**			−0.1442**		
	(-2.28)			(-2.12)		
did_active		0.0019			0.0109	
		(0.05)			(0.28)	
did_price			0.1671			0.3866
			(0.27)			(0.64)
_cons	4.9426***	4.8840***	4.8904***	2.8218**	2.7621**	2.7795**
	(3.81)	(3.75)	(3.76)	(2.36)	(2.28)	(2.32)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
ID/Year	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
Region × year	Yes	Yes	Yes	Yes	Yes	Yes
N	3962	3962	3962	3962	3962	3962
R2	0.9410	0.9408	0.9408	0.9668	0.9666	0.9667

Robust t-statistics in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Standard errors are clustered to province.

Table 8
Political incentives on political statement.

	(1)	(2)	(3)	(4)
	Atten_env	Atten_eco	Atten_env	Atten_eco
DIDset	1.9275**	1.6597***	2.1427***	1.1419***
	(2.30)	(4.78)	(3.15)	(2.99)
_cons	33.5235***	19.3019***	−27.4972	111.1214***
	(333.96)	(463.90)	(-1.01)	(6.09)
Control variables	No	No	Yes	Yes
ID/Year	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Province	Yes	Yes	Yes	Yes
Region × year	Yes	Yes	Yes	Yes
N	3662	3662	3419	3419
R2	0.5677	0.3653	0.5809	0.3791

Robust t-statistics in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Standard errors are clustered to province.

the "pilot" status increases the local government's concern for ecological environment and economic development, regardless of whether the control variables are included or not. Hypothesis H2-1 is verified. As mentioned in the policy introduction and theoretical analysis of this paper, China's CETS pilot project is a market-based regulatory policy in the field of ecology and environment, which aims to achieve carbon emission reduction targets at a lower economic cost. This suggests that the central government does not want local governments to give up their economic growth targets in order to reduce emissions. As a result, we see in the empirical results that the pilot regions have increased their emphasis on environmental goals while at the same time increasing their emphasis on economic goals. However, the magnitude of the estimated coefficients indicates that the pilot regions are more positive in their attitude towards environmental goals (In Table 8, the coefficients of DID 2.1427 > 1.1419).

In summary, the results in Table 8 show that due to the absolute authority of the central government in China's hierarchical administrative system, the behavior of local governments is inevitably influenced by the policy preferences of the central government. Therefore, environmental protection policies implemented on a pilot basis, even if such policies are based on market laws, bring political incentives to local governments. This political incentive is essentially a manifestation of the Hawthorne effect.

6.2.2. Actual performance of local government

Since Table 8 only shows the impact of the pilot policy on the political statements of local governments, the actual policy impact should still be examined from the actual actions. Therefore, this paper re-regresses the actual performance of local governments in environmental protection and economy as the explanatory variables, and obtains the estimation results as shown in Table 9.

Drawing upon the outcomes presented in the initial column of Table 9 (the coefficients of DID is −0.0331*), it becomes evident that the implementation of China's CETS pilot initiative is associated with the mitigation of regional PM2.5 levels. When combined with the notably negative coefficient observed for carbon emissions in the baseline regression, it implies that the pilot policy has evidently motivated local governments to intensify their endeavors towards ecological conservation. This practical action to protect the ecological environment is not only for carbon emissions, but also for other aspects such as air quality. Combined with the results in Table 8, the pilot policy has prompted local governments to show more active efforts on environmental protection in their political statements and practical actions. This suggests that in a highly centralized administrative system, once the central government really pays attention to environmental issues, the action strategies of local officials in competition for promotion will move closer to the preferences of the central government.

According to the results in the second column, China's CETS leads to a decrease in local governments' efforts to achieve economic growth targets. The regression coefficients indicate that the Unplanned-Growth in the pilot districts declined by about 0.64 percentage points. Hypothesis H2-2 is verified. What is the real meaning of this decrease? In other words, does it mean that the local governments in the pilot areas have actually abandoned their economic growth targets? We can get an answer from the economic growth rates in the

Table 9
Political incentives on actual performance.

	(1)	(2)	(3)	(4)
	lnPM25	EcoPerf	GDPgrow	GrowAmp
DIDset	−0.0331*	−0.6440**	−0.8163**	0.2637
	(-1.77)	(-2.54)	(-2.06)	(1.67)
_cons	4.0123***	−2.2695*	6.1432***	15.9866
	(13.69)	(-1.80)	(2.94)	(1.45)
Control variables	Yes	Yes	Yes	Yes
ID/Year	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Province	Yes	Yes	Yes	Yes
Region × year	Yes	Yes	Yes	Yes
N	3962	3607	3607	3679
R2	0.9693	0.4873	0.7660	0.6441

Robust t-statistics in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Standard errors are clustered to province.

descriptive statistics. We find that the average real economic growth rate of Chinese cities is about 10%, while the average value of the economic growth target is the same. This means that even though local governments have reduced the level of their economic growth efforts, they are still using the targets they set at the beginning of the year as the bottom line. In other words, local governments have not given up on economic development altogether, but have merely reduced their efforts to achieve excessive growth.

We also conduct a regression analysis with the real growth rate and the top-down amplification behavior of the growth target as explanatory variables, and the results are shown in the third and fourth columns of Table 9. The findings indicate that China's CETS is associated with a 0.8 percentage point reduction in economic growth, reaching significance at the 5% level. This result corresponds exactly to the dampening effect on unplanned growth in the second column. Notably, the coefficient in the fourth column displays a positive trend but lacks statistical significance. The likely reason behind this phenomenon is that local governments' establishment of economic growth targets serves as a public political statement in itself. Given that the CETS pilot policy from the central government clearly indicates that carbon emission reduction should not come at the cost of economic development, local governments are compelled to maintain a stance that emphasizes GDP growth in their public statements. On the other hand, the economic GDP target disclosed in the government work report represents a public commitment to both the residents of the region and higher government authorities. Once this target is set, every possible effort must be made to achieve it. However, if this target is unrealistically high, it inevitably increases the challenge of meeting carbon reduction objectives. Consequently, local governments are constrained to balance their commitment to economic growth without setting excessively ambitious targets, thereby avoiding unnecessary constraints. This situation leads to the positive but not statistically significant coefficients indicated in the fourth column of Table 9.

Bringing together the insights from Tables 7 and 8, the influence of China's CETS pilot program on the political incentives of local governments manifests in both the "verbal" and "behavioral" aspects. Regarding ecological environmental governance, local authorities exhibit a strategy of "alignment between rhetoric and actions". In other words, high-profile political statements do translate into positive practical actions. However, concerning economic development, local governments demonstrate a measure of "discordance between words and actions." Prominent statements are not consistently supported by correspondingly proactive steps in practical implementation.

6.2.3. *Dynamic effects of political incentives*

We evaluate the dynamic effects of the aforementioned political incentives, and the outcomes are depicted in Fig. 6. Fig. 6(a) and (b) show that the pilot policy has raised the local government's attention to ecological environment and economic development. This political incentive persisted for at least three years following the policy's release, after which the significance level of the regression coefficient decreased. Two factors could be to blame for the outcomes mentioned above: (1) The incentives for the pilot areas to make a "high-profile" political statement is diminished as time goes on because the central government's special attention to the pilot areas is not sustainable; (2) under political incentives, the high-profile remarks of the pilot areas led to the competitive imitation of the non-pilot areas. The difference between the treatment group and the control group became less significant as a result of these two factors.

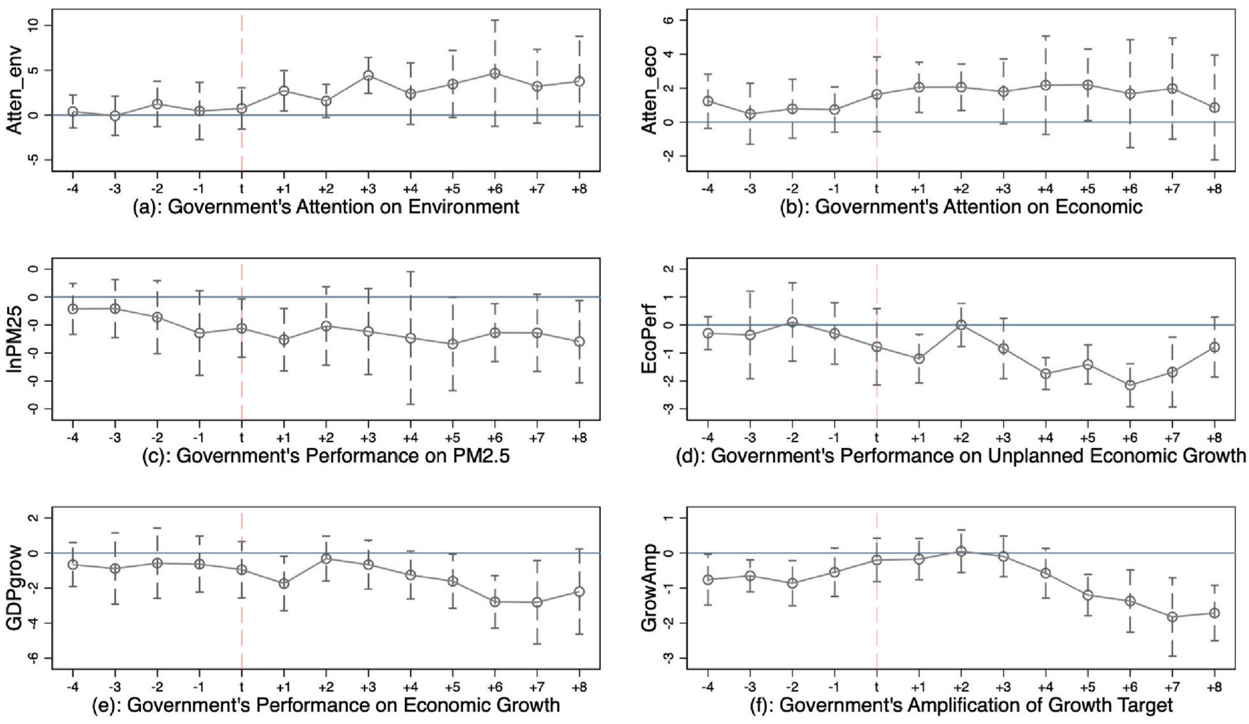

Fig. 6. Dynamic effects of political incentives.

Fig. 6(c) demonstrates that the carbon trading pilot strategy has an unstable impact on PM2.5, with a significant effect in some years and insignificant in others. This implies that there may be a preference for campaign governance in the environmental actions of local governments, and that the political rewards of the CETS pilots may have strengthened this inclination. The central government is paying attention to this problem.

The unplanned economic growth was long-term dampened by the pilot strategy, as shown by Fig. 6(d). However, this dampening effect starts to fade starting in the sixth year following the policy shock. When combined with Fig. 6(e) and (f), this attenuation is not due to the pilot areas performing better in terms of economic growth rates; rather, it is due to the fact that the top-down amplification of the economic growth target is suppressed. In other words, the better performance was not due to greater effort, but to lowered evaluation criteria.

Moreover, Fig. 6(f) also explains why the regression coefficients in the fourth column of Table 9 do not fail the significance test. The extent to which the pilot regions ramped up in setting economic growth targets in the three years following the release of the pilot list is up, which corresponds to the window between the release of the pilot list and the official operation of the market. In terms of behavioral motivations, the pilot regions anticipated that the carbon market would reinforce the central and public focus on environmental targets such as carbon emissions reduction, which would limit the flexibility of local governments in their economic growth efforts. Therefore, during the policy window of the preparatory phase of the carbon market, the pilot regions seek additional economic development opportunities by reinforcing their economic growth targets, thereby compensating for the potential economic costs of the carbon market launch. With the official activation of the carbon market, the excessive amplification of the economic growth target will only exacerbate the dilemma faced by local governments. This motivation is thus reduced.

6.3. Further analysis

6.3.1. Welfare effects of pilot policy

Based on the above analysis, we conclude that China's CETS pilot has formed political incentives for local officials, leading them to adjust their strategies in multi-task management to cater to their superiors' preferences. Given that local governments in China often contend with a multitude of responsibilities, requiring the allocation of administrative resources across different priorities such as economic growth, environmental protection, and public welfare, an elevated focus from higher-level governments on a specific task might lead to a reduced emphasis on other obligations [26]. Essentially, multi-objective management in local government refers to the process of allocating limited administrative resources to each governance objective. Thus, once the CETS pilot is politically motivated, its impact will be felt beyond the governance objectives that the policy content focuses on. In addition to environmental protection and economic growth, providing basic public services to residents in their jurisdictions is also a key task for local governments. Especially since the Communist Party of China (CPC) has always stressed its aim to serve the people wholeheartedly, local governments face pressure from both the central government and residents in their jurisdictions to provide basic public services. Hence, we aim to explore the broader implications of China's CETS policy on additional governance objectives.

We evaluate the impact of CETS policies with local government's attention to social welfare and actual performance as explained variables. The results are shown in Table 10. The variable *Atten_welf* indicates the overall attention of local governments to social welfare, which specifically includes five aspects: public safety, medical and health care, urban and rural community affairs, education, social security and employment. We focus on the attention of local governments in three aspects: education (*edu*), medical (*med*) and transportation (*tsp*). In addition, when examining the actual impact of the pilot policy on social welfare, we only consider the education and health aspects due to data availability. Among them, education supply is measured by the teacher-student ratio of primary and secondary schools, and medical supply is measured by the number of practicing or assistant doctors per 10,000 people.

From the empirical results in Table 10, the first column shows that CETS pilot inhibited local governments' attention to social welfare. However, we are more concerned with the coefficients of DID in the second, third, and fourth columns. According to the regression results, the pilot policy caused the decrease of local government's attention to the public service of transportation, but had no significant impact on the attention of education and medical care. The reasons are as follows: transportation is more closely related to economic development, which is more likely to cause the increase of carbon emissions; However, education and medical care are

Table 10
Welfare effects of pilot policy.

	(1)	(2)	(3)	(4)	(5)	(6)
	Atten_welf	Atten_edu	Atten_med	Atten_tsp	Supply_edu	Supply_med
DIDset	−2.4653***	−0.3034	0.1515	−0.7895*	0.3744	−0.9634***
	(-3.00)	(-1.33)	(1.00)	(-1.86)	(1.34)	(-2.84)
_cons	−5.6720	9.1316	−1.9066	24.5566**	9.7870**	−41.7806
	(-0.35)	(1.56)	(-0.58)	(2.68)	(2.47)	(-1.28)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
ID/Year	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
Region × year	Yes	Yes	Yes	Yes	Yes	Yes
N	3419	3419	3419	3419	3962	3962
R2	0.4647	0.3566	0.3656	0.4567	0.8372	0.7164

Robust t-statistics in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Standard errors are clustered to province.

public services directly related to people's livelihood issues, and the higher authorities and the people in their jurisdiction have stronger supervision over them, which makes the local government dare not easily reduce the importance of them. According to the regression results in the fifth and sixth columns, the medical supply in the pilot area is inhibited (coefficient is −0.9634, passing the 1% significance test), while the impact on the educational supply is not significant. The reason may be that under the household registration system, only local residents can enjoy the educational resources in the area; Under the insurance reimbursement system, residents can obtain medical services in the whole province and even the whole country. As a result, local governments have insufficient incentives for the supply of public medical services.

When China's CETS led to a shift in administrative resources towards environmental goals, health public services topped the list of "goals that will be abandoned" by local governments. The comparison between the third and sixth columns in Table 10 highlights that, in situations where administrative resources are redirected from other governance objectives to address priorities emphasized by higher-level governments, local governments are compelled to signal their unwavering commitment to those other goals through public statements. However, in practice, local governments will unavoidably need to diminish their dedication to certain objectives, including healthcare and more ambitious economic growth targets.

6.3.2. SDM-DID

According to the analysis in this paper, the pilot policy distorts the political incentives of local governments. In this case, it is likely to lead to the relocation of high-emission enterprises to non-pilot areas with weaker environmental regulatory intensity, and the result is a spatial leakage effect of carbon emissions. However, some studies argued that China's carbon pilots have a spatial emission reduction effect [10,13,58]. This conclusion seems to be difficult to harmonize with the conclusions of this paper. In order to further verify the reliability of the conclusions of this paper, we draw on the methodology of related studies Jia et al. [59]. We combine the double difference model (DID) with the spatial Durbin model (SDM) into the SDM-DID model to test the spatial spillover effect of CETS on carbon emission reduction. Specifically, we choose the economic distance weight matrix for SDM-DID regression.

As shown in Table 11, the coefficient of DID is always negative regardless of the introduction of control variables, and the coefficient of the interaction term W × DID is positive, indicating that the pilot program caused carbon leakage effect or pollution paradise effect. The above conclusion echoes the study of Gao et al. [60]. In sum, the conclusion further confirms the hypotheses H2-1 and H2-2 of this paper, as China's CETS pilot distorts the political incentives of local governments, which makes the pilot regions give more prominence to environmental objectives, and thus leads to the relocation of high-emission firms to non-pilot regions.

Lesage and Pace suggest decomposing the effects to obtain direct and indirect effects [61]. Table 11 also presents the outcomes of the decomposition analysis. Upon close examination of the findings in columns 3 and 4, it becomes evident that the direct effects exhibit a pronounced negative orientation, bearing statistical significance at the stringent 1% threshold, thereby maintaining alignment with the baseline results. In parallel, the coefficient associated with the indirect effect emerges as positive and attains statistical significance at the 5% significance level, thereby lending support to the proposition of a pollution haven effect. It is worth noting that the total effect coefficient, although positive, does not pass the significance test. By amalgamating the findings from Tables 8 and 10, a comprehensive perspective emerges on the impacts of China's CETS. While the scheme appears effective in curbing carbon emissions within the pilot area, attributed to the Hawthorne effect, it simultaneously engenders a carbon leakage phenomenon. This complex interplay ultimately prevents the realization of the emission reduction objectives on an overarching scale. As a consequence, the extrapolation of this policy across the entire nation necessitates a concerted effort to mitigate any potential distortion of political incentives at the institutional level.

7. Conclusions and policy implications

7.1. Conclusions

This research investigates the emission reduction benefits of CETS in China and its mechanisms based on a multi-period DID model using a sample of 283 cities from 2006 to 2019. In contrast to previous studies, instead of considering local government administrative intervention in environmental governance as an exogenous variable, this paper treats it as an outcome of endogenous political incentives influenced by the CETS pilot policy. This advancement in research ideas has reference value for evaluating the outcomes of policy experiments conducted in a hierarchical administrative structure with both centralized and decentralized features, such as China's. Of course, when it comes to measuring carbon emissions, the accuracy of data for each city is limited due to data constraints, a common challenge in existing literature. Therefore, this paper selects a measurement method that closely approximates the real-world situation among the available options. Nonetheless, the research presented in this paper remains highly significant. This is due to the extensive body of literature that supports the effectiveness of CETS in China. While the carbon emission data in this paper, like much of the existing literature, is estimated rather than actual, it does not undermine the examination of emission reduction mechanisms. It is in this aspect that this paper makes a unique and valuable contribution. The conclusions of this paper are as follows.

Firstly, the CETS pilot program in China has successfully reduced emissions by a large amount. A long-lasting emission reduction effect also surfaced after the list of pilots was revealed. The empirical findings demonstrate that CETS, as a market-based environmental regulation, enhances the market mechanism's contribution to the effect of emission reduction. The effectiveness of CETS in reducing emissions increases with market development. However, because China's carbon trading system is still in its early stages of development, market incentives do not account for all of the emission reduction effect.

Secondly, although while the existing studies had demonstrated that administrative intervention would strengthen the CETS pilot's ability to reduce emissions [19–21], this paper goes further in explaining why local governments do this. This paper finds that the pilot

Table 11
Spatial spillover effect of CETS on carbon emission reduction.

	(1)	(2)	(3)	(4)
	lnCO2gdp	lnCO2	lnCO2gdp	lnCO2
DIDset	−0.2262***	−0.2353***	−0.2550***	−0.2535***
	(-4.70)	(-4.46)	(-6.51)	(-5.82)
W × DIDset	0.2310***	0.2586***	0.3239***	0.3164***
	(3.53)	(3.76)	(6.06)	(5.68)
rho	0.7849***	0.7866***	0.7242***	0.7424***
	(10.52)	(11.17)	(9.22)	(9.63)
Direct effect of DIDset	−0.2165***	−0.2223***	−0.2367***	−0.2355***
	(-4.67)	(-4.30)	(-6.32)	(-5.62)
Indirect effect of DIDset	0.2749	0.3737	0.5365**	0.5265**
	(0.99)	(1.29)	(2.35)	(2.24)
Total effect of DIDset	0.0584	0.1514	0.2998	0.2910
	(0.22)	(0.54)	(1.37)	(1.31)
Control variables	NO	NO	Yes	Yes
ID/Year	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
AIC	−3565.24	−3791.12	−3869.31	−4037.53
BIC	−3527.56	−3753.43	−3630.63	−3798.86
r2	0.0067	0.0299	0.1503	0.0202
N	3948	3948	3948	3948

Robust t-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1. Standard errors are clustered to province.

policy leads to the Hawthorne effect. China's CETS, as a pilot project, changed the original political incentives, leading to more high-profile political statements about environmental protection and economic development in pilot regions. Local governments, however, are not always consistent in their words and actions, and the increased focus on a particular goal does not mean devoting more administrative resources to ensuring that goal is achieved. This is particularly relevant given the continuing conflict between environmental preservation and economic growth, as well as the fact that a number of environmental management strategies, including reducing carbon emissions, have somewhat reduced "off-target economic growth." In other words, from the perspective of political incentives, the China's CETS, as a pilot project, is characterized by "campaign-style governance". This obviously contradicts the carbon market's initial goal. In view of the above, on July 30, 2021, the Political Bureau of the CPC Central Committee proposed to rectify "campaign-style" carbon reduction. Since then, Chinese officials have repeatedly emphasized that local governments should avoid setting overly ambitious and unrealistic goals or simply chanted slogans without taking actions in carbon emission reduction actions.

Thirdly, in the extended analysis, this paper finds that: (1) China's CETS pilot has led local governments to place less emphasis on public services that tend to increase carbon emissions, such as transportation. In addition, local governments' emphasis on environmental goals has led to a crowding out of resource investment in other goals. However, since local governments often cannot significantly cut down their investments in economic goals, they tend to reduce funding in areas like healthcare public services. This is because healthcare services can often be piggybacked from other regions through "free-riding". This approach, akin to "tearing down the east wall and patching up the west wall," could ultimately lead to an unsustainable approach to carbon emissions governance. (2) China's CETS pilot has led to carbon leakage to non-pilot regions with close economic proximity. Obviously, this carbon leakage effect exacerbates the imbalance of carbon emissions between pilot and non-pilot regions. Nonetheless, this outcome doesn't stem directly from the inherent nature of the CETS policy, which operates as a market-based environmental regulation. Rather, it can be attributed to the specific political incentives generated by the pilot status. Thus, this beggar-thy-neighbor "polluter's paradise effect" will no longer be present when CETS is expanded from regional pilots to national scale. This is because the special status of the pilot will no longer exist and the associated political incentives will disappear.

7.2. Policy implications

Firstly, enhancing market mechanisms and address political incentives. As indicated in this paper and confirmed by other studies, administrative interventions have shown to positively influence carbon reduction efforts. However, it's crucial to acknowledge that the core principle of market-based environmental regulation revolves around utilizing market mechanisms, rather than extensive government intervention, to achieve cost-effective carbon emission reductions. Consequently, it is imperative to recognize that an overreliance on government intervention may not be a sustainable long-term approach. To realize the full potential of China's CETS, it is imperative to strengthen market mechanisms while considering the influence of political incentives. This can be achieved by fostering innovative strategies in the carbon trading market to optimize the efficiency of carbon pricing mechanisms. Furthermore, when allocating carbon quotas, a more market-oriented approach should be adopted, incorporating sector-specific carbon footprints to promote market-driven emission reductions. By addressing both market mechanisms and political incentives, the CETS can maximize its effectiveness in reducing emissions.

Secondly, establishing an institutionalized regulatory system to avoid "Campaign-Style" governance. Without a well-defined institutional environmental governance system in place, the central government's environmental governance strategies can be disproportionately magnified by local governments, potentially leading to unintended consequences such as reductions in social welfare and economic growth. In order to ensure consistent and effective environmental governance, it is recommended to establish a robust regulatory framework that prevents the adoption of "campaign-style" governance methods. Regulatory policies should provide clear and transparent guidance to all stakeholders, minimizing arbitrary interventions by local governments. Collaborative efforts between government agencies, industry players, and environmental experts should be encouraged to design and implement regulations that align with the broader goals of sustainability and economic growth, avoiding the one-size-fits-all approach.

Thirdly, tailoring emission reduction targets to regional realities in officials' appraisals. For a more practical approach, we suggest setting emission reduction targets based on the unique developmental context of each region. Policymakers should consider factors such as environmental governance, economic development, and public welfare, with varying emphasis according to regional needs. This approach, as opposed to a uniform standard, acknowledges the diversity of regions and promotes a balanced approach to policy implementation on environmental goals, economic development and social welfare.

Data availability statement

The relevant data can be downloaded from MacroData (https://www.macrodatas.cn). The authors have spent a lot of effort in organizing these data, which can be obtained from the corresponding author of this paper if interested.

CRediT authorship contribution statement

Jiafei Bai: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Conceptualization. **Wentao Ma:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yuxin Wang:** Writing – review & editing, Project administration, Funding acquisition, Formal analysis. **Jiayue Jiang:** Writing – original draft, Visualization, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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