Study on the Synergistic Governance Effect of Carbon Emissions Trading Policy on Pollution Reduction and Carbon Abatement

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Abstract. Based on the background of China's "Carbon peaking and Carbon neutrality" strategy, this study selects the panel data of 30 provincial-level administrative regions from 2013 to 2022, constructs a multi-period difference-in-differences model (DID), and systematically examines the environmental synergistic effect of the carbon emissions trading policy. Through empirical tests, it is found that the carbon trading policy not only significantly reduces carbon dioxide emissions in the pilot areas, but also enables the $PM_{2.5}$ concentration to decrease, confirming that the policy has a significant collaborative effect of pollution reduction and carbon reduction. The study provides a theoretical basis for improving the design of carbon market mechanism and promoting environmental synergistic governance.

Keywords: carbon emission trading policy, pollution and carbon reduction

1 Introduction

1.1 Research Background

Historically, humanity relied heavily on fossil fuels, driving economic growth but emitting vast greenhouse gases like CO_2, exacerbating climate change. As the world's top emitter (28% of global CO_2), China committed to "dual carbon goals" in 2020: peaking emissions by 2030 and achieving neutrality by 2060. To facilitate this, China launched a national carbon market, leveraging market mechanisms to curb emissions and pollution simultaneously, given their shared sources (e.g., coal plants emitting CO_2 and NO_x). Progress includes coal's energy share dropping 12.5% since 2012, non-fossil energy rising to 18.5%, and $PM_{2.5}$ levels falling 45% since 2013. However, challenges remain: coal dominates power generation (60%), renewables face grid limitations, industrial transitions are costly, and regional disparities persist. Despite improvements, achieving carbon neutrality demands overcoming structural and technological hurdles.

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1.2 Research Significance

This study focuses on the synergistic governance effect of carbon emissions trading policies in terms of pollution reduction and carbon reduction. By constructing a three-dimensional analytical framework of "policy instruments - market response - synergistic effect", it explores how the carbon emissions trading policy can realize the dual objectives of environmental governance through the market-oriented mechanism, providing new perspectives for academic research in the fields of environmental economics and climate governance. Secondly, the inclusion of data from 2021, when China's carbon trading market is fully opened, will facilitate further theoretical exploration of the concept of "synergistic governance". Furthermore, evaluating the dual effects of carbon trading on emission reduction and pollution control provides empirical evidence for refining policy goals and governance strategies in the context of China's environmental policy framework.

At the practical level, this study offers important policy references for the optimization and improvement of China's carbon emissions trading policy. With the gradual construction of China's carbon market, enhancing governance efficiency and leveraging synergistic effects between pollution reduction and carbon reduction have become urgent issues. Through empirical analyses and policy assessments, the results of this study will provide decision-making references for government policy makers on how to balance carbon reduction targets while taking into account other environmental objectives such as air quality improvement, thus forming a multi-objective synergistic governance system.

In addition, this study can also provide practical operational guidance for enterprises to respond to the carbon emissions trading policy. By integrating carbon and pollutant emission reduction strategies, businesses can achieve a win-win situation of economic and environmental benefits, driving green transformation through optimized resource allocation and low-carbon innovation.

2 Literature Review

2.1 Carbon Emissions Trading Policy

The carbon emissions trading policy is a market-based environmental regulatory tool, the core of which is to achieve greenhouse gas emission reduction targets at the lowest cost by setting a cap on the total amount of carbon emissions and allocating quotas, allowing enterprises to trade emission rights. The policy originated from the 1997 Kyoto Protocol, China launched a local pilot program in 2011 and formally established a national carbon market in 2021, covering 2,225 key emission units in the power industry, making it the largest carbon market in the world. he policy promotes the optimization of energy structures and guides capital investment in new energy and energy storage through quota constraints and carbon price incentives. Financial tools such as carbon quota pledges and green bonds accelerate the commercialization of low-carbon technologies. By 2024, the national carbon market had a turnover of 43 billion yuan.

Under the goal of "dual carbon", academia have conducted extensive research on the multifaceted impacts and mechanisms of carbon emissions trading policies using methods such as double-difference modelling, propensity score matching combined with DID, and generalized synthetic control methods. Existing studies affirmed the positive role of carbon emission trading in carbon reduction, supported by official monitoring data. The 2024 National Carbon Market Development Report released by The Ministry of Ecology and Environment shows that in 2023, China's thermal power carbon emission intensity decreased by 2.38%, and the carbon intensity of electricity generation decreased by 8.78% from 2018. The implementation of carbon trading cumulatively cut 250 million tons of CO_2 emissions in the power sector. Sectoral data revealed differences in emission reduction effects across industries, with chemical, iron and steel industries showing more significant reductions. Regional emission reduction effects also vary due to differences in market elements and mechanism design, with Beijing having the strongest effects, followed by Guangdong and Hubei being relatively weaker. Technological drivers in the eastern region and contributions from energy transitions in the west are prominent. In addition, carbon emissions trading policies also play a important role in guiding capital flows to low-carbon areas and promoting economic transformation.

In summary, Hypothesis 1: Carbon credits can reduce CO_2 emissions .

2.2 Synergistic Governance Effects of Carbon Emissions Trading Policies for Pollution Reduction and Carbon Reduction

The concept of pollution and carbon reduction can be traced back to 1991, when Ayres et al.[1] and others suggested that greenhouse gas emission reductions could simultaneously reduce pollutant emissions.

Research on pollution and carbon reduction in China originated from studies on the environmental benefits of China's carbon market. In terms of policy effects, studies have generally confirmed that carbon emissions trading policies have significant synergistic effects on pollution and carbon reduction. Yan et al. (2020)[2] first explicitly proposed the existence of synergistic effects in China's carbon market, testing significant reduction in haze pollution concentrations in pilot areas of China's emission trading system.. Based on the panel data of 250 cities in China, Shao et al. (2023)[3] used a spatial Durbin double difference model, found that the pilot carbon emissions trading policy remarkably reduced SO_2 emissions in the pilot areas, but had a negative spatial spillover effect on neighboring areas(i.e., SO_2 pollution may worsen in neighboring areas). At the same time, the policy improved $PM_{2.5}$ concentrations in both the pilot regions and their surrounding cities, indicating positive spatial spillovers effects in the governance of atmospheric pollutants. Zhang Guoxing et al. (2022)[4] used a double difference model, treated the carbon trading pilot policy as a quasi-natural experiment, confirming that the policy had synergistic effects in reducing carbon emission intensity and $PM_{2.5}$ and SO2 concentrations based on the panel data of 276 prefectural-level cities in China from 2006-2018, considering the carbon trading pilot policy as a quasi-natural experiment. Li (2021)[5] explored the relationship and impact mechanism between carbon market pilots and air pollution, using daily air pollution data from 324 cities above the prefecture level in China from December 1, 2013, to December 18, 2017, concluding that carbon market pilots could reduce at least 4.9% of air pollution, especially for sulfur dioxide, inhalable particulates, and fine particulates. Xue Fei et al.(2021)[6] demonstrated that there is a carbon emission reduction effect of the carbon trading market scale, and due to the existence of homologation between carbon dioxide and other atmospheric pollutants, the carbon trading market can play a synergistic emission reduction effect to reduce SO2 emissions. Zhang Xuechun et al. (2024)[7] validated the policy's outstanding effect on $PM_{2.5}$ emission reduction using the synthetic control method, with more significant synergistic effects in developed areas such as Beijing, Shanghai, and Guangzhou. Li Feng (2025)[8] also paid extra attention to the impact of the carbon trading pilots on industrial dust and wastewater emissions, finding that the carbon trading pilot significantly reduced SO_2 and $PM_{2.5}$ concentrations, but had no striking impact on industrial wastewater and soot and dust emissions, indicating that the policy effect was pollutant selective. It is worth noting that some studies (e.g., Su Mengjiao, 2022)[9] point out that the synergistic emission reduction effect of carbon trading policies on air pollutants may be weaker than the direct effect on carbon emissions, which may be related to the heterogeneity of pollutant emission sources.

In the research on the mechanisms of pollution and carbon reduction by carbon emission trading, the existing literature reveals multiple dimensions of policy action paths, mainly through industrial structure upgrading, technological innovation driving, energy structure optimization and the transfer of polluting industries. Yan et al. (2020)[2] argue that the emission reduction effect of the pilot carbon emissions trading system may be achieved through the application and transformation of green technologies in enterprises and the heavy polluting industries' transfer; Ye Fangyu et al. (2022)[10] also regarded green technology innovation as a key mediating variable, but Su Mengjiao (2022)[9] pointed out that its effect is limited and requires strengthened policy guidance and R&D support. Ding Liyuan et.al (2023)[11] believed that the policy achieved simultaneous reduction of CO_2 and air pollutants through the two paths of reducing energy consumption and improving energy structure, but industrial structure adjustment did not have a transmission effect yet. Xu Hao (2023)[12] and Ye Fangyu et al. (2022)[10] both found that carbon trading policies forced high-energy-consuming industries to transform, promoting industrial structure adjustment towards low-carbonization. Zhu Siyu (2023)[13] examined the synergistic effects of emission trading and carbon emission trading from the perspectives of pollution control and policy management, finding that both types of policies significantly reduced SO_2 and CO_2 emissions, with combined policies having a greater advantage in SO_2 emission reduction, while separate carbon trading had a better effect on CO_2 emission reduction, suggesting the necessity of synergistic design of policies. Zhou, Hsing (2023)[14] examined the synergistic governance effects of local government environmental regulations and carbon trading system, and the results showed that local government environmental regulation increased carbon emissions of enterprises, while carbon trading system can correct this unfavorable effect and alleviate the defects of strategy selection in government policy implementation.

In addition, scholars have conducted extensive research on the spatial heterogeneity of synergistic effects of pollution reduction and carbon reduction. Jing Xue (2024)[15] found that the synergistic effect of pollution reduction and carbon reduction showed a gradient distribution of "low in the west and high in the east" through the Bayesian causal forest model, with more significant effects in the eastern region due to the advantages of economic foundation and technology level. Li Ronghua (2023)[16] found that the emission reduction effect of carbon emission rights trading showed obvious gradient differences from the east, to the middle to the west, with strongest effect in the western region, followed by the centraland the weakest in the east. This difference mainly stems from the fact that the western region has a greater potential for energy structure transformation, while the eastern region is more likely to achieve emission reduction through technological innovation due to a better foundation in green technology. For example, western pilot cities achieved significant emission reductions through energy intensity improvements and energy structure transformations, while the eastern region relied on green technologies progress. Zhu (2022)[17] studied three pilot regions, Guangdong, Chongqing and Hubei, and found that while carbon emissions were reduced in all of them, the reduction of SO_2 emissions in Guangdong and Chongqing far exceeded that in Hubei. Zhou Peng et al. (2023)[18] further found that the pilot markets in Hubei and Shanghai had a significant inducing effect on corporate green innovation, higher than other regions, but the carbon price signal had not yet effectively stimulated innovation. Li Feng et al. (2025)[8] found that carbon trading pilots at the power plant level reduced CO_2 by 38.61% while simultaneously cutting SO_2 by 52.19% and nitrogen oxides by 48.62%, with more significant effects in old industrial bases and environmentally focused cities. Therefore, hypothesis two is proposed: carbon emission rights can improve the effect of pollutant emission reduction.

3 Empirical Analysis

3.1 Modelling

In view of the significant homology between atmospheric pollutants and carbon emissions in , this study considers the carbon emissions trading policy as a natural experiment, empirically analyses the differential impacts of this policy on carbon dioxide emissions and atmospheric pollutant emission reductions across 30 provinces by using a double difference model (DID), and explores in depth explores the mechanism of the policy-induced synergistic effects of pollution reduction and carbon reduction. Referring to the model of Hu Yufeng et al., introducing the interaction terms of time dummy variable ($Time_{it}$) and province dummy variable ($Treated_i$), a multi-period double difference model is constructed as follows:

$$Y_{it} = \beta_0 + \beta_1 Treated_i \times Time_{it} + \gamma X_{it} + \delta_t + \varepsilon_i + \epsilon_{it} \quad (1)$$

Where:

Y_{it} is the dependent variable representing the carbon dioxide emissions or atmospheric pollutant emissions measured by $PM_{2.5}$ concentration in province i at year t. $Treated_i$ is a province dummy variable, assigned a value of 1 for provinces which have implemented the carbon trading emission policy and of 0 for those that do not.

$Time_{it}$ is a time dummy variable, distinguishing before and after the policy implementation. It takes a value of 0 before the policy and 1 after. With a view to accurately identifying the effects of the carbon trading policy implementation, the interaction term of the province and time dummy variables, $Treated_i \times Time_t$ is introduced, reflecting the status of the policy implementation. A value of 1 indicates that the province has implemented the carbon trading policy. X_{it} is a collection of all control variables, including GDP, energy consumption, population density, etc., which reflect the level of economic and social development of each province, affecting the environment and air quality, which is conducive to improving the accuracy of the regression. δ_t is the fixed effect for each province, and ε_i is the time fixed effect, used to eliminate the influence of individual and time-level heterogeneity on the model results. ϵ_{it} is the random disturbance term, reducing the interference to the prediction accuracy due to unobserved factors, measurement errors of variables, etc. β_0 is the intercept term. β_1 is the core parameter of the model, whose estimated value characterizes the net policy effect of carbon trading policy. Specifically, when β_1 is significantly negative, it indicates that the implementation of the carbon trading mechanism can simultaneously reduce carbon dioxide emissions and air pollutant concentrations; if β_1 is significantly positive, it suggests that the implementation of the policy may push up carbon emissions and pollution levels in the opposite direction.

Indicator Construction.

Dependent variables

(1) CO_2 emissions. To quantify the level of carbon emissions, this study performs a natural logarithmic transformation to the total CO_2 emissions, constructing an indicator of carbon emission levels, $\ln CO_2$.

(2) $PM_{2.5}$ concentration value. $PM_{2.5}$, also known as fine particulate matter, refers to particles in the ambient air with an aerodynamic equivalent diameter of 2.5 micrometers or less.

Core explanatory variables: According to the different time points of carbon emissions trading policy implementation, different provinces are divided into different policy implementation batches to construct a multi-period DID model. The core explanatory variable is the interaction term $Treated_i \times Time_{it}$. $Treated_i$ is a provincial dummy variable, taking a value of 1 if the province is an area implementing the carbon emission trading policy, otherwise 0.

The interaction term of two dummy variables $Treated_i \times Time_{it}$ is constructed specifically to assess the effects of carbon trading policies. $Treated_i$ distinguishes between carbon trading pilot and non-pilot provinces, $Time_{it}$ precisely defines the timing of policy implementation. For each province, the interaction term is assigned a value of 1 in the year when the province is approved as a carbon trading pilot and beyond, and a value of 0 before approval. By interacting these two variables, it is possible to identify changes in carbon emissions and atmospheric pollution indicators in pilot provinces compared to non-pilot provinces after the implementation of the carbon trading policy in multi-period panel data, thereby quantifying the net synergistic effects of pollution reduction and carbon reduction brought about by the policy.

Control variables: Energy Consumption, Gross Domestic Product (GDP) of each region, The Added Value Of The Primary Industry, Industrial Structure, Population Density are used as control variables.

3.2 Data Sources and Statistical Analyses

Panel data of 30 provincial-level administrative regions in China from 2013 to 2022 (excluding Tibet Autonomous Region, Hong Kong Special Administrative Region, Macao Special Administrative Region and Taiwan Province) are selected as the sample for analysis.

The relevant data come from Cathay Pacific Database (CSMAR), The National Bureau of Statistics of China, and the China Statistical Yearbook. The descriptive statistics of the variables are shown in Table 1.

Table 1. Descriptive statistics

variant	average value	(statistics) standard deviation	minimum value	maximum values	observation volume
$PM_{2.5}$	38.751	14.727	14.354	93.225	300
CO_2	45635.14	35419.15	5518.908	243218.5	300
GDP	29116.06	23781.38	2134.605	119740.8	300
IND	2237.566	1490.879	105.94	5848.4	300
IND_str	1.421	0.751	0.71	5.128	300
People_des	474.096	712.884	8.021	3933.333	300
lnenergy	9.479	0.643	7.575	10.64	300

As evident from the above table, the standard deviation of CO_2 emissions as the dependent variable is 35,419.15, which is a very large value, and there is also a huge difference between the minimum and maximum values of $PM_{2.5}$ concentration, indicating significant disparities in carbon dioxide emission levels and pollutant concentrations among different provinces, which is probably due to the different industrial structures and energy consumption patterns in each province. The control variables reflect the heterogeneity in economic, social development levels and industrial structures among provinces, and thus the possible effects of carbon trading policies may vary among provinces.

3.3 Benchmark Regression and Parallel Trend Tests

Analysis of Baseline Regression Results.

Using the double difference method to evaluate the effects of carbon trading policies on the reduction of carbon dioxide and air pollutant emissions, the empirical results are shown in Table 2 and Table 3.

Table 2. Regression results for CO_2 emissions

variant	lnCO2	lnCO2	lnCO2
did	-0.148	-0.0977***	-0.258***
	(-1.627)	(-2.617)	(-5.146)
lnenerge		1.257***	1.259***
		(29.86)	(30.59)
gdp		-4.29e-06***	-4.15e-06***
		(-3.598)	(-3.553)
ind		-6.24e-05***	-7.59e-05***
		(-3.302)	(-4.054)
ind_str		-0.0537*	-0.0626**
		(-1.951)	(-2.255)
people_des		-4.41e-05	-1.32e-05
		(-1.473)	(-0.438)
Constant	10.51***	-1.060***	-1.109***
	(191.2)	(-2.732)	(-2.916)
Observations	300	300	300
R-squared	0.009	0.869	0.879
F	2.647	324.0	137.5

It can be observed that, in terms of CO_2 abatement, the introduction of control variables produces a significant inhibitory effect of the carbon emissions trading policy with an effect coefficient of -0.0977 at the 1% significance level. Further controlling for time- fixed effects, it is found that the inhibitory effect has been significantly enhanced, with an effect coefficient of -0.258, which is also valid at the 1% significance level, suggesting that the control of macro shock over time strengthens the identification of policy effect. This may be because the time- fixed effects isolate changes solely caused by the policy, excluding the impact of common shocks in the time dimension such as economic cycles and fluctuations in energy price.

Table 3. Regression results on $PM_{2.5}$ concentration

variant	pm	pm	pm
did	7.514***	-8.144***	-3.784***
	(-4.387)	(-4.672)	(-3.727)
lnenerge		10.88***	-11.64***
		(5.538)	(-2.597)
gdp		-0.000157***	-0.000772***
		(-2.826)	(-10.49)
ind		-0.00126	0.00228*
		(-1.429)	(1.857)
ind_str		-0.717	-23.73***
		(-0.558)	(-13.93)
people_des		0.00613***	0.320***
		(4.387)	(7.889)
Constant	41.51***	-55.90***	-132.9**

variant	pm	pm	pm
	(40.02)	(-3.086)	(-2.236)
Observations	300	300	300
R-squared	0.061	0.240	0.898
F	19.24	15.46	66.40

According to the regression results in Table 3, it is found that the carbon trading policy also has a significant reducing effect on $PM_{2.5}$ emissions, with coefficients of -7.514, -8.144, and -3.784 under the conditions of no control variables, introduction of control variables, and inclusion of province fixed effects, respectively, which also hold at the 1% significance level.

Overall, in different settings such as the baseline model, adding control variables, and incorporating bidirectional fixed effects, the estimated coefficient of the core explanatory variable consistently remains negative, with a significance level maintained at the 1% threshold, verifying the effectiveness of the carbon trading policy's synergistic pollution reduction and carbon reduction effects.

The synergistic governance effect of carbon trading policies has also been widely confirmed in concrete practice. The Shanghai carbon market incorporates green power offsetting carbon emissions volume into its rules, allowing enterprises to directly offset their quota demand by purchasing green electricity from the Beijing Power Exchange Center's green power trading platform. Estimated at an average carbon price of 67.25 yuan per ton, 13 Shanghai carbon trading enterprises deducted a total of 360 million kWh of green power purchased through the platform in 2022, equivalent to 151,000 tons of carbon emissions, saving about 10.15 million yuan in compliance costs. Shanghai Baosteel, as a key emitting unit in the national carbon market, purchased quotas through the carbon trading market and implemented ultra-low emission environmental protection upgrades for transformation. In 2023, Baosteel purchased 900 million kWh of green electricity, equivalent to 400,000 tons of carbon dioxide emissions reduction. At the same time over 50 environmental protection upgrades were implemented, including desulphurization of coke oven gas and comprehensive utilization of steelmaking slag, etc., resulting in a 35% reduction in sulfur dioxide emissions intensity and a 40% reduction in particulate matter emissions intensity. Cost constraints and incentives for green electricity deductions drive steel enterprises from "passive emission reduction" to "proactive environmental protection," achieving "multiple effects with one treatment" by reducing carbon emissions and cutting atmospheric pollutants. In 2023, the court in Laohekou City, Xiangyang, Hubei Province, handled a case involving the endangerment of precious wildlife. The defendant purchased and cancelled 617 tons of carbon allowances (valued at 27,800 yuan) through the Hubei Carbon Market as a substitute for ecological restoration responsibilities. This is the first case in Hubei province where "carbon credit" was used to fulfill ecological restoration responsibilities, and it is also the first cooperative case after the signing of the Hubei "Innovation in Ecological and Environmental Judicial Protection in the 'Dual Carbon' Field Cooperation Agreement." 617 tons of carbon quotas are equivalent to the carbon sequestration of planting 34,000 trees， and their role in carbon reduction is beyond doubt. The funds of carbon quota transactions will be used for wetland restoration, indirectly reducing agricultural surface pollution (e.g. pesticide and fertilizer loss), improving water purification capabilities and reducing ammonia, nitrogen emissions. The Carbon trading policy, through market pricing and judicial linkage, transforms the environmental responsibility of enterprises or individuals into economic costs, achieving the closed loop of "Carbon Reduction - Pollution Control - Ecological Restoration".

3.4 Parallel Trend Test

There should be the same development trend in the observations of the test group and the control group before the policy implementation, which is the premise of the DID model. Only after passing the parallel trend test can the model be further constructed for policy effect analysis. The test results are shown in Figure 1.

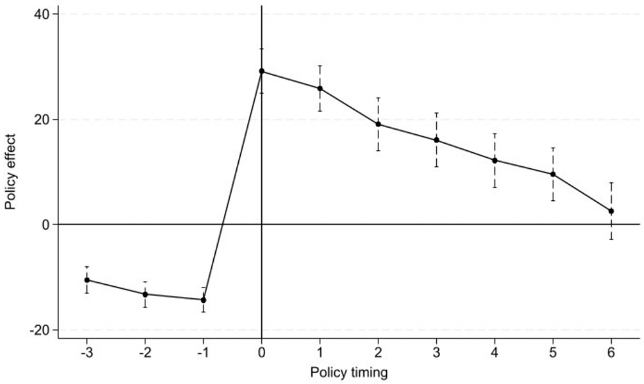

Fig. 1. Parallel trend test for CO_2

Specifically, the magnitude of changes in CO_2 levels at t = -3, -2, -1 before the policy implementation (t < 0) is not significant, suggesting that the trend of CO_2 emissions in the treatment and control groups was similar before the policy implementation, supporting the parallel trend hypothesis. Negative values may imply that the treatment group had relatively lower CO_2 levels or a smaller downward trend before the policy. A clear jump occurred at the time of policy implementation (t = 0), indicating a sharp short-term surge in CO_2 levels at the beginning of the policy. This may be attributed to firms "jumping the gun" before the policy took effect, speeding up production with the intention of avoiding carbon quota restrictions. After the implementation of the policy (t > 0), the CO_2 level gradually decreased indicating that the carbon credits policy is beginning to take effect, prompting enterprises to reduce their emissions. Although the downward trend in CO_2 emissions continued, the rate of decline gradually slowed down, which may indicate that the reduction effect is stronger at the initial stage, but as the policy was adapted, the marginal benefits of enterprise emission reduction diminished. There may be a surplus of allowances or a weakening of price signals in the carbon market, making long-term emission reduction less effective.

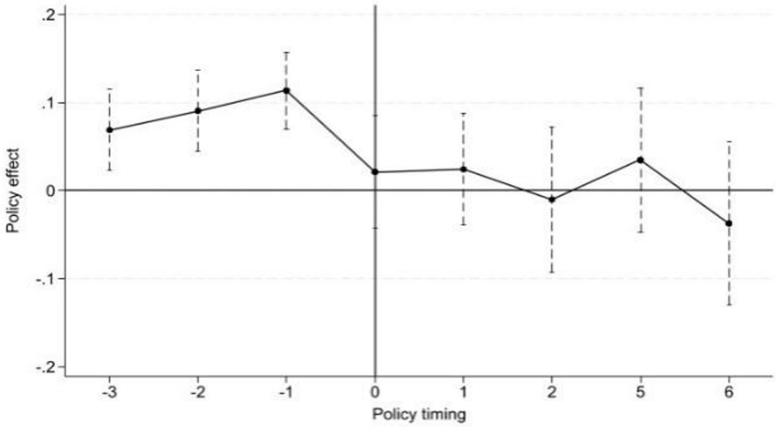

Fig. 2. Parallel trend test for $PM_{2.5}$

Figure 2 illustrates the situation before and after the policy implementation.Before the policy implementation ($t < 0$) $PM_{2.5}$ exhibited an upward trend, but the overall increase was relatively small and the point estimate was close to 0, indicating that the trend of concentration change between the treatment and control groups before the policy remained consistent, which satisfied the parallel trend assumption and ensured the causal inference basis of the study. There was a significant and substantial decrease in $PM_{2.5}$ concentrations at the time of policy implementation ($t = 0$). After the implementation of carbon trading policy (time points 1, 2, 5, and 6), the concentration showed a fluctuating trend. After the carbon trading policy has been implemented, enterprise emission reduction is a gradual process. Initially, to meet the policy requirements, enterprises may focus on short-term emission reduction measures (e.g., temporary production restriction) to quickly reduce $PM_{2.5}$; however, in the long term, to balance the cost of production and emission reduction, it is also necessary to adjust the progress through technological upgrading, replacement of traditional energy by clean energy, and other slow progress, but with long-term effect. Enterprises need to continuously explore lower-cost emission reduction strategies, leading to fluctuations in policy effects at different stages.

3.5 Robustness Check

For the purpose of evaluating the reliability of the regression method and the explanatory power of the indicators, a robustness test is carried out using the method of winsorizing the data. The empirical results obtained after data processing are shown in the Table4 and Table5. The DID coefficient of carbon trading policy remained consistent in sign before and after the winsorizing process, and is significantly negative at the 1% level after controlling for time and province fixed effects, indicating that the conclusion of the study is still valid after the data truncation, and the robustness test is passed, the carbon trading policy has the synergistic effect of lowering the emissions of CO_2 and $PM_{2.5}$.

Table 4. Effect of shrinkage treatment on CO_2

variant	$lnCO_2$	$lnCO_2$
did	-0.0941**	-0.257***
	(-2.527)	(-5.132)
lnenerge	1.268***	1.270***
	(29.92)	(30.69)
gdp	-4.44e-06***	-4.30e-06***
	(-3.678)	(-3.628)
ind	-6.27e-05***	-7.65e-05***
	(-3.307)	(-4.078)
ind_str	-0.0522*	-0.0617**
	(-1.879)	(-2.207)
people_des	-4.44e-05	-1.30e-05
	(-1.482)	(-0.432)
Constant	-1.165***	-1.215***
	(-2.979)	(-3.174)
Observations	300	300
R-squared	0.870	0.880
F	325.9	138.7

Table 5. Impact on $PM_{2.5}$ after winsorizing treatment

variant	pm	pm
did	-8.137***	-3.400***
	(-4.666)	(-3.419)
lnenerge	10.93***	-12.57***
	(5.507)	(-2.834)
gdp	-0.000158***	-0.000832***
	(-2.791)	(-11.26)
ind	-0.00127	0.00246**
	(-1.432)	(2.055)
ind_str	-0.736	-23.24***
	(-0.566)	(-13.65)
people_des	0.00615***	0.343***
	(4.382)	(8.433)
Constant	-56.28***	-156.3***
	(-3.075)	(-2.612)
Observations	300	300
R-squared	0.240	0.902
F	15.41	69.19

4 Summaries

4.1 Findings

Using the multi-period DID model to evaluate whether the carbon trading policy has a synergistic effect on reducing pollution and carbon emissions, the research results show that this market-based environmental regulation can not only significantly reduce carbon emissions but also significantly reduce $PM_{2.5}$ concentrations, verifying the synergistic governance effect of the carbon trading policy.

4.2 Policy Recommendations

Based on the conclusions of this paper, the article suggests the following countermeasures.

First, strengthening the rules and institutional construction of the carbon trading market to promote the standardization of carbon trading behaviors. From the research results, carbon trading policy has a significant synergistic emission reduction effect. However, at present, there are no laws or administrative regulations on the management of carbon emissions trading in China, and the operation of the national carbon emissions trading market is based on the regulations and documents issued by relevant departments of the State Council, which is of a lower legislative level and insufficient authority, making it difficult to meet the practical needs of regulating trading activities, guaranteeing data quality, and punishing illegal behaviors, etc. It is necessary to formulate a specialized administrative regulations to provide a clear legal basis for the operation and management of the national carbon emissions trading market, and give full play to the role of the market mechanism as a tool for controlling greenhouse gas emissions and promoting the achievement of green and low-carbon goals.

Second, expanding trading entities and trading products. The power generation industry is currently the only industry included in the national carbon trading market, and the development of the market is lagging. The Ministry of Ecology and Environment has made it clear that in 2025 the national carbon market will be mandatorily expanded to the three major industries of iron and steel, cement and electrolytic aluminum, significantly increasing trading volume and encouraging the participation of more market players in the carbon trading market.

At last, the governance strategies and objectives should be formulated according to local conditions to maximize policy effectiveness. The empirical results show that the emission reduction effect of the carbon trading policy varies across provinces. Environmental pollution management needs to be combined with local resource, environmental conditions and the level of economic development to formulate scientific,reasonable goals and paths for pollution reduction and carbon reduction.

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