Research on the effectiveness of Carbon Market Pilot Policies

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Abstract. The carbon trading market is widely recognized as a crucial tool in the effort to combat climate change and alleviate greenhouse gas emissions. It is essential to evaluate its effectiveness in implementation. To achieve this aim, we utilized the Differences-in-Differences (DID) method to analyze carbon emission data spanning from 2007 to 2020 across various provinces in China. The primary objective is to empirically investigate the impact of China's carbon emissions trading mechanism on regional carbon emissions. Results show that the implementation of the carbon emissions trading mechanism has played a positive role in reducing carbon emissions. The research identifies a significant positive correlation between the level of economic development (GDP) and foreign direct investment (FDI) with carbon emissions. Additionally, there is a positive association between the volume of proposals addressing environmental issues and carbon emissions. In summary, this study provides valuable insights into the effectiveness of China's carbon emissions trading mechanism, offering important lessons for future policy development and the optimization of the carbon market.

Keywords: Carbon Emissions Trading, Difference-in-Difference Model (DID) , Carbon Emission Reduction

1. Introduction

Early carbon trading programs were implemented through systems such as the Clean Development Mechanism (CDM) and the European Union Emissions Trading System (EUETS) under the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement's principal goal is to prevent global warming to a maximum of 2 degrees Celsius over pre-industrial levels, with a more ambitious goal of keeping it to 1.5 degrees Celsius. Each country is anticipated to formulate national contributions tailored to its unique circumstances in order to fulfill these climate targets.

The Chinese government is committed to achieving its carbon peak and carbon neutrality goals, utilizing the emissions trading market as a key tool. In 2013, China embarked on carbon market pilot projects in seven regions, including Beijing, Tianjin, Shanghai, Chongqing, Guangdong, Henan, and Hubei. These initiatives have gradually established and improved the carbon trading system. Operating through mechanisms such as allocation, trading, disclosure, and verification, China's carbon market has evolved over time.

In steadfast adherence to the regulations outlined in the Paris Agreement, the Chinese government envisions that the introduction of the carbon emission market will effectively mitigate greenhouse gas emissions, laying a solid foundation for the ultimate goal of achieving carbon neutrality and establishing a robust framework encompassing both policy and technology for the future realization of carbon neutrality. This holistic approach is poised to make a positive contribution to China's long-term sustainable development.

Amidst ongoing economic development and increased worldwide awareness about carbon emissions, Chinese citizens are increasingly prioritizing the carbon emissions issue. In response to the global call for carbon control, China is committed to achieving a peak in carbon dioxide emissions by 2030 and aspires to attain carbon neutrality by 2060. This commitment entails reaching net-zero

overall carbon emissions before 2060, ensuring that the amount of carbon absorbed equals the amount emitted, leading to a comprehensive reduction in carbon emissions.

The Chinese government has established a number of policies and actions targeted at actively contributing to the achievement of carbon emission targets. These initiatives are strategically designed to incentivize the reduction of carbon emissions, with the overarching goal of making significant strides in carbon emission reduction. However, a crucial question remains concerning the efficacy of China's carbon emission market in achieving emission reduction through these implemented policies and measures. This paper is dedicated to a thorough and critical examination of this central issue, serving as its primary focus.

2. Literature review

2.1. Carbon market related research

From the existing body of research, scholars have primarily focused on the investigation of carbon trading markets with respect to their nature and development (He and Li, 2010), the mechanisms within carbon trading markets (Yang, 2010; Chen and Lu, 2016), and carbon prices (Yu, 2018; Yang, 2020). The term “carbon trading market” refers to the trade of carbon emission permits, especially carbon dioxide, a greenhouse gas. This’s can be attributed to due to the predominant presence of carbon dioxide in greenhouse gases, thus rendering the emission trading of greenhouse gases collectively as "carbon trading" (He and Li, 2010) [1]. Yang (2010) expounded upon the theoretical foundations of carbon trading market mechanisms, analyzed the challenges inherent in the development of the carbon trading market within the context of China, and provided insights into issues such as regulatory strengthening and legal safeguards [2]. Chen and Lu (2016) delved into the nine fundamental elements comprising the carbon emission trading system, considering aspects like legal foundations, compliance mechanisms, and pricing mechanisms. Their results suggest that the establishment of a nationally unified carbon trading market operational mechanism should occur in two distinct phases [3]. Yu (2018) conducted a study on the carbon prices in Shanghai, Guangdong, and Hubei, discovering that their prices exhibited leverage effects and that price volatility was more influenced by positive returns [4]. Yang (2020) employed fifteen indicators to study the factors affecting carbon prices. Through empirical analysis, it was revealed that carbon prices are influenced slowly and erratically by factors such as traditional energy prices and the natural environment. [5]. Simultaneously, an increasing number of scholars are recognizing the need for a comprehensive assessment of the interconnections between the carbon trading market and other markets. Wang(2019) conducted an in-depth investigation into the volatility spillover effects and dynamic correlations between China's carbon emissions quota market and fossil energy markets. The study results indicate that the dynamic correlation between fossil energy markets and regional carbon emissions quota markets displayed time-varying trends [6].

In addition to the difficulties raised above, the fast expansion of the carbon trading market has piqued the interest of academics both at home and abroad in terms of market efficiency. Foreign scholars employ various empirical methods to examine market efficiency, aiming to gain deeper insights into the operation of carbon markets. Daskalakis (2013) investigated the efficiency of four types of carbon dioxide (CO_2) emission allowance futures traded on the Intercontinental Exchange (ICE) between 2008 and 2011. It was found that the market reached weak-form efficiency from 2010 onwards, thus demonstrating the gradual maturation of the European carbon market [7] .Rhodes(2016) researched the relationship between market liquidity and efficiency in the European Climate Exchange, revealing that greater market liquidity leads to reduced predictability of yield returns. The efficiency of the European Union carbon trading market in the second phase is gradually strengthening [8].

Domestic scholars are also conducting market efficiency analyses in various regional carbon markets to gain a better understanding of the characteristics and potential issues in domestic carbon markets. Xu (2017) used a GARCH(1,1) model to test the return rates in the Shenzhen carbon market

with a random walk test and concluded that Shenzhen had not reached weak-form efficiency. They recommended improving China's carbon market development by strengthening related legislation, ensuring fair initial quota allocation, and promoting innovation in carbon products [9]. Zhao and Wang (2018) conducted a market efficiency analysis using the Beijing, Shanghai, Guangdong, and Hubei carbon markets as examples. They found that the Hubei carbon market had achieved weak-form efficiency, Beijing had not, and Shanghai and Guangdong, while not currently efficient, were expected to become more efficient as they developed further [10].

2.2. Relevant studies on factors affecting carbon emissions

Carbon emissions have long been seen as one of the most serious threats to global environmental sustainability and growth. Carbon emissions on a large scale not only have a considerable influence on the climate system, but also on other areas of the economy, society, and ecosystems. Pethig (2014) argued that in a country implementing carbon trading, continuing green subsidies would reduce the country's welfare level. However, smaller countries, by not subsidizing green energy, can effectively operate carbon trading, while larger carbon-emitting importing countries can influence permit prices in their favor by subsidizing green energy [11]. Sun(2014) conducted an in-depth analysis of how carbon trading markets affect China's macroeconomy under different carbon reduction goals. They used the 2007 social accounting matrix to construct a CGE model for China's carbon trading market [12].

As the issue of greenhouse gas emissions becomes increasingly pressing, scholars are delving deeper into the study of factors influencing carbon emissions. These factors encompass various aspects, including the economy, energy, population, and urbanization. These studies further unveil the interrelationships between carbon emissions and other key factors. Zhao(2019) analyses the regional differences in carbon emissions and the factors influencing them during the urbanisation process between 1995 and 2012, and the study shows that both the economic level and population size have a positive impact on the contribution of carbon emissions.[13]. Gao and Han (2022), from a municipal perspective, used spatial panel models and other techniques to study the factors influencing carbon emissions in the Yellow River Basin. The results show that carbon emissions in the Yellow River Basin are on the rise, but the growth rate has slowed down, with regional economic growth being the primary influencing factor for carbon emissions [14].

3. Data and Methodology

3.1. Data

Since 2013, several Chinese regions including Shenzhen, Shanghai, Beijing, Guangdong, Hubei, Tianjin, Chongqing, and Fujian have progressively established carbon market trading. In 2021, a nationwide unified carbon market specifically for the power generation sector was also launched. This study encompasses all 31 provinces and cities of China, covering the period from 2007 to 2021.

The dataset utilized in this research comprises both environmental and economic-related data across the 31 provinces and cities. The environmental data is primarily sourced from the *China Environmental Yearbook* and *Statistical Yearbook*, while the economic data is derived from the Statistical Yearbook. Given that the *China Environmental Yearbook* for 2021 is not yet fully updated, and it is not feasible to acquire recommendations from People's Congress representatives or proposals from the Chinese People's Political Consultative Conference (CPPCC), this study addresses the missing values using the following approach: missing values are imputed based on the growth rate formula $X_t+1=X_t+[(X_t-X_{t-1})/X_{t-1}]*X_t$ resulting in a comprehensive dataset with a total of 465 observations.

3.2. Variables

In economic research, the selection of variables is usually based on theoretical guidance and prior literature. In this study, our variable selection also follows this principle.

Dependent Variable. The carbon emissions of each province and city serve as a direct indicator to measure the effectiveness of government policies on carbon emission control. Naturally, carbon emissions become the preferred dependent variable (Aldy and Stavins, 2011)[15]. This is consistent with the common practice of environmental policy assessment worldwide, ensuring the comparability and international applicability of our research results.

Independent Variable. The implementation dummy variable of the carbon emission rights trading policy. Considering that the introduction of the carbon emission rights trading policy is the main focus of this paper,

Control Variables. (i) Number of Proposals Regarding Environmental Issues from People's Congress Representatives and CPPCC Members (x_1). Referencing the study by Kahn and Matsusaka (1997), governments typically consider public opinion and pressure during the policy implementation process[16]. The number of proposals regarding environmental issues reflects the government's attention and investment in environmental protection. Therefore, as a control variable, it helps us to more accurately measure the effect of the carbon emission rights trading policy itself; (ii) Gross Domestic Product (x_2). According to the Environmental Kuznets Curve theory (Grossman and Krueger, 1995), there is a certain relationship between economic development and environmental pollution. Therefore, incorporating GDP as a control variable helps us to exclude the impact of economic development on carbon emissions, allowing for a more precise estimation of the policy effect[17]; (iii) Foreign Direct Investment(x_3) . Foreign direct investment has a "pollution halo" effect, significantly impacting carbon emissions in both the local and adjacent areas (Li Yueming, Li Xinfei et al., 2023)[18]. Therefore, FDI is considered an important variable affecting carbon emissions.

The policy effect was identified by comparing the changes in carbon emissions before and after the policy implementation across different provinces. At the same time, we conducted parallel trend hypothesis tests and placebo tests to verify the reliability and robustness of our results.

3.3. Empirical strategy

In response to the global challenge of climate change, the Chinese government has initiated the carbon emission rights trading policy, aiming to leverage market mechanisms to curb greenhouse gas emissions across various provinces and cities. This policy is being implemented progressively in a phased and regional manner, creating a natural experimental setting for evaluating its effects. In this study, we adopt the Difference in Differences (DID) method as the main analytical framework, constructing the following model to assess the impact of the carbon emission rights trading policy:

$$Y_{it}=\beta_0+\beta_1 Policy_{it}+\beta_2 X+\alpha_i+\gamma_t+\epsilon_{it} \quad (1)$$

where Y_{it} represents the carbon emission. $Policy_{it}$ is the interaction term of the policy dummy variable and time dummy variable, used to capture the implementation effect of the policy. It takes a value of 1 when the policy is implemented in the ith province/city in year t if it is when the policy put forward, and 0 otherwise. X represents the set of control variables, including the number of suggestions from People's Congress representatives and proposals from the CPPCC on environmental issues, Gross Domestic Product (GDP), and Foreign Direct Investment (FDI); α_i and γ_t are the fixed effects of region and time, respectively; ϵ_{it} is the error term of the model. β_0 is the intercept term, representing the baseline expected carbon emissions when the policy is not implemented and all explanatory variables are 0; β_1 is the policy effect coefficient, reflecting the average impact of policy implementation on carbon emissions; β_2 is the coefficient of the control variables, showing the association between these variables and carbon emissions. All variables are logarithmic.

4. Results and Analysis

4.1. Baseline results

When considering the factors affecting carbon emissions in various provinces and cities of China, we adopted a random effects generalized least squares regression model.

Table 1. Regression Results

	Coef.	Std.Err	z	P>z
did	-0.156517	0.0272273	-5.75	0.000
lnx1	0.0236161	0.011722	2.01	0.044
lnx2	0.4095536	0.0213613	19.17	0.000
lnx3	-0.0443977	0.0142286	-3.12	0.002
_cons	6.922969	0.2369017	29.22	0.000

The coefficient β_1 is -0.1565, significant at the 1% significance level (Table 1). This means that, compared to provinces that did not implement the policy, the carbon emissions of provinces that implemented the policy are expected to decrease by approximately 15.65%, controlling for other factors. This significant policy effect is worth delving into to understand the underlying mechanisms, mainly from the following three perspectives:

Government Level: The implementation of the carbon emission rights trading policy has enhanced the policy enforcement of local governments in environmental protection. The policy provides local governments with a concrete and operable tool for emission reduction. Guided by the policy, local governments are more likely to take effective measures to promote carbon emission reduction in their regions.

Enterprise Level: On one hand, it improves carbon emission efficiency. In provinces that implement the carbon emission rights trading policy, enterprises are more inclined to adopt low-carbon or clean energy and improve energy efficiency to reduce the purchase of carbon emission quotas. This directly leads to a decrease in carbon emissions per unit of output, thereby enhancing the carbon emission efficiency of the entire province. On the other hand, it promotes the research and development and application of low-carbon technologies. The establishment of the carbon trading market encourages enterprises to invest more resources in the research and development of low-carbon technologies, seeking more economical emission reduction paths. This not only helps to reduce the enterprise's own carbon emissions but also promotes the dissemination and application of low-carbon technologies throughout the province.

Individual Level: It enhances public awareness of environmental protection. The establishment and operation of the carbon emission rights trading market have raised public awareness of carbon emission reduction and strengthened society's attention to environmental issues. The formation of this public opinion atmosphere helps to promote the implementation of policies and achieve carbon emission reduction goals.

We have also controlled the impact of three other economic variables to reduce omitted variable bias and improve the accuracy of the estimates. As Table 1 presents, the coefficient for the number of proposals is 0.0236, with a $p < 0.05$, indicating that the growth in the number of proposals is positively correlated with the growth in carbon emissions to a certain extent. The coefficient for GDP is 0.4096, with a $p < 0.01$, indicating a significant positive correlation between GDP growth and carbon emission growth. The coefficient for FDI is -0.0444, with a $p < 0.05$, suggesting that FDI growth is positively correlated with a reduction in carbon emissions to a certain extent.

The negative coefficient and significance of the policy dummy variable (Policy) support the view that the carbon emission rights trading policy can significantly reduce carbon emissions. It should be noted that although we have controlled the impact of the other three economic variables, these variables themselves are also significantly related to carbon emissions. Specifically, the number of proposals and GDP are significantly positively correlated with carbon emissions, while FDI is

significantly negatively correlated with carbon emissions. The inclusion of these control variables enhances our confidence in the policy effects, as they reduce the bias that may arise from omitting other key variables to a certain extent.

4.2. Robustness checks

While the baseline regression outcomes of this study corroborate our anticipated research hypothesis, it is crucial to acknowledge that potential endogeneity issues such as omitted variables could introduce bias to our results. Therefore, to affirm the robustness and validity of our baseline findings, we have engaged in a series of robustness tests, employing methodologies such as parallel trend analysis and placebo tests.

4.2.1. Parallel Trend Test

When executing the Difference in Differences (DID) strategy, adherence to the parallel trend assumption is paramount. This prerequisite mandates that prior to any intervention, in this case, the implementation of a policy, the trajectory of the outcome variable (carbon emissions herein) should exhibit parallelism between the treatment and control groups. Upholding this assumption is crucial as it validates that any post-intervention variances observed in the outcome variable can be legitimately ascribed to the intervention itself, and not to other temporal trends.

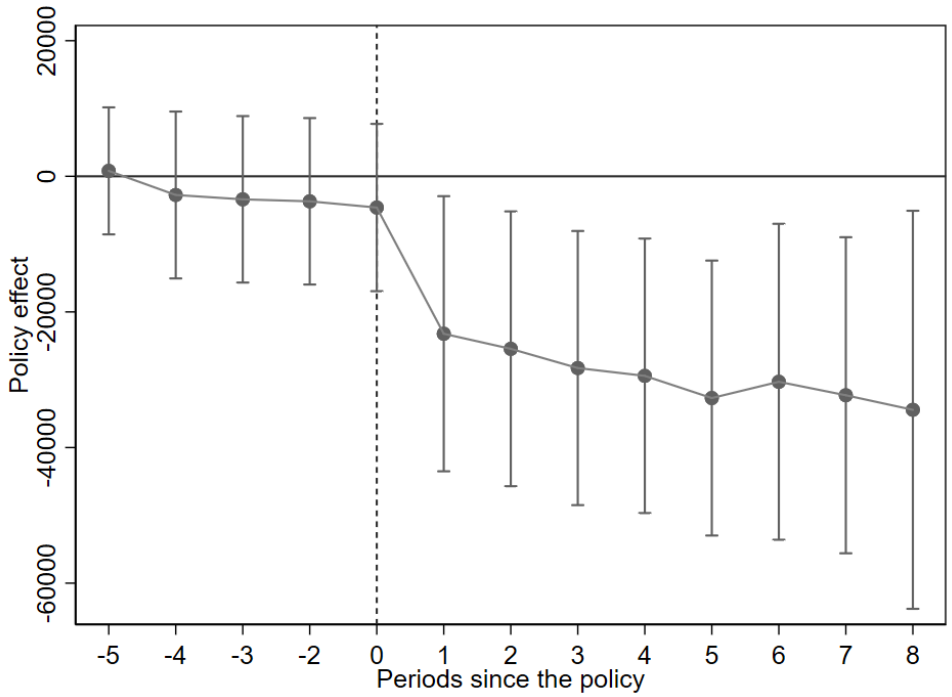


Figure 1. The test for parallel trend assumption

The results of our parallel trend test lend credence to this assumption in Fig. 1. Prior to the policy's activation, the carbon emission trends within both the treatment and control groups demonstrated a remarkable parallelism. To be more precise, at multiple time points leading up to the policy's enactment, the confidence intervals surrounding the coefficients of the treatment effects predominantly straddled zero, signifying their statistical insignificance. This observation underlines that, in the pre-policy phase, the carbon emission patterns of provinces and cities, irrespective of their group classification, mirrored each other, thereby affirming the validity of the parallel trend assumption.

Post-policy implementation, however, we discerned significant effects. The data particularly underscored a pronounced decrease in carbon emissions within the treatment group, commencing from the policy's inaugural year. This revelation aligns seamlessly with our initial hypothesis, positing that the advent of the carbon emission rights trading policy would culminate in a tangible reduction of carbon emissions.

This segment of our analysis fortifies the credibility of our model's estimations and further corroborates our principal conclusion, asserting a significant and inverse relationship between the implementation of the carbon emission rights trading policy and regional carbon emissions.

4.2.2. Placebo Test

To enhance the robustness of our estimation results and mitigate potential biases arising from model configurations or unobserved heterogeneity, we proceeded with a placebo test. This involved utilizing pre-policy implementation data to artificially "generate" policy effects at a hypothetical point of policy enactment. This approach enables us to scrutinize the presence of any spurious policy effects at the presumed time of policy introduction, affirming the robustness of our primary findings. In the ensuing sections, we will delve comprehensively into the setup and outcomes of this placebo test.

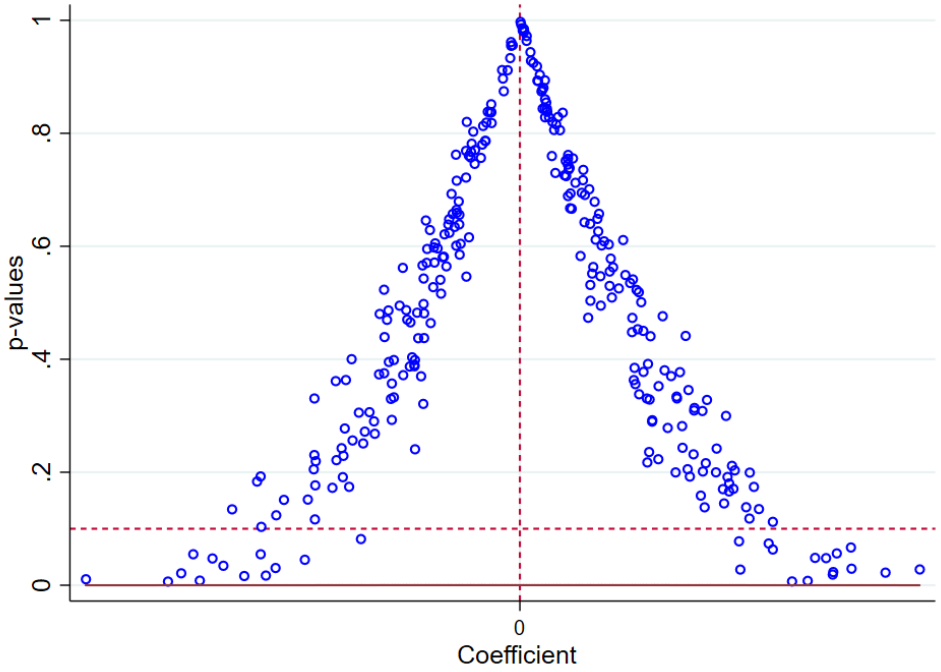


Figure 2. The Placebo Test

Examining the graphical representation of the placebo test outcomes, as depicted in Fig. 2, it is evident that the estimated coefficients for the fictitious policy effects cluster around zero, assuming a shape that closely resembles a normal distribution. This is indicative of a healthy model, suggesting the absence of any systematic policy effects in scenarios void of policy intervention. Furthermore, the majority of p are above 0.1, denoting the lack of significant policy effects at these hypothetical points of policy introduction.

These observations lend credence to our prior assertion that the estimates derived for the effects of the carbon emission rights trading policy are indeed robust. The placebo test outcomes illustrate that fabricating a policy effect at a juncture devoid of actual policy implementation typically yields non-significant policy effect estimates. This outcome solidifies the credibility of our main findings, establishing a clear linkage between the actual policy implementation and a noticeable reduction in carbon emissions.

Engaging in a thorough and nuanced analysis and validation of our model, we now possess a reinforced understanding of the genuine impact exerted by the carbon emission rights trading policy across various provinces and cities in China. The foundational regression analysis elucidates a pronounced negative correlation between the policy variable and carbon emissions across different regions, while control variables such as the number of proposals, GDP, and FDI exhibit logical associations with the dependent variable. Subsequent parallel trend tests uphold our DID model assumptions, confirming the absence of significant discrepancies in carbon emission trends between the treatment and control groups prior to policy enactment. In our placebo test, by introducing

fictitious policy variables in contexts where no policy was in effect, we observed an absence of significant policy impacts, thereby fortifying the validity of our principal conclusions.

5. Conclusion and Implications

This article adopts the Difference in Differences (DID) method, based on carbon emission data from multiple provinces in China, to conduct an in-depth analysis of the impact of China's carbon emission rights trading mechanism on regional carbon emissions. By evaluating the impact of the implementation of the carbon emission rights trading policy in various provinces at different times, the following conclusions are drawn.

(1) The carbon emission rights trading mechanism indeed played a positive role in reducing carbon emissions after its implementation. Specifically, after controlling for other factors, the carbon emissions of provinces that implemented the carbon emission rights trading policy are on average 15.65% lower than those that did not implement the policy, verifying the effectiveness of the carbon emission rights trading mechanism as a market-oriented environmental policy tool in promoting regional carbon reduction.

(2) the study also found that the level of economic development (GDP) and foreign direct investment (FDI) are significantly positively correlated with carbon emissions, while the number of proposals related to environmental issues is positively correlated with carbon emissions. These findings reveal the significant impact of economic activities and social attention on carbon emissions, emphasizing the need to comprehensively consider the roles of economic development and social participation while promoting carbon reduction.

Based on these conclusions, we derive the following implications:

(1) **Deepen and Optimize the Carbon Emission Rights Trading Mechanism**: The study shows that the implementation of the carbon emission rights trading policy has indeed led to a significant reduction in carbon emissions. Based on this finding, the government should further deepen and optimize the carbon emission rights trading mechanism to ensure that it can play a more effective role. This includes improving market transparency, optimizing quota allocation methods, and strengthening supervision of market manipulation behaviors to ensure the fair and effective operation of the carbon market.

(2) **Promote Successful Experiences and Expand the Coverage of the Carbon Market**: Given the positive effects achieved in some regions after implementing the carbon emission rights trading policy, the government should summarize the successful experiences of these regions and, based on this, gradually expand the coverage of the carbon market to include more industries and regions in the carbon trading system.

(3) **Increase Support for and Promotion of Low-Carbon Technologies**: To achieve a greater degree of carbon reduction, relying solely on market mechanisms is not enough; technological support is also needed. The government should enhance investment in the research and development of low-carbon technologies and provide policy and financial support to promote the innovation and application of low-carbon technologies.

(4) **Enhance Public Awareness and Participation in Carbon Reduction**: Carbon reduction is a major event that requires the participation of the whole society, and it needs widespread awareness and participation from the public. The government should strengthen the publicity and education of carbon reduction and the carbon trading mechanism, create a good atmosphere for the whole society to participate in carbon reduction, and encourage the public to actively participate in carbon reduction actions.

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