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Can Carbon Exchanges Policies Promote Carbon Emission Reductions? Evidence from China

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Abstract

The natural ecological environment and the sustainable growth of the world economy are seriously threatened by global warming. This research uses a quasi-natural experiment approach to the implementation of carbon pricing policies, based on panel data collected from 281 Chinese cities between 2008 and 2017. By constructing a multi-period difference-in-differences model, this paper assesses how the Chinese government's carbon exchanges program has reduced carbon emissions. The empirical findings demonstrate that the carbon exchanges policy's implementation significantly reduces carbon emissions, and this policy does not achieve carbon diminution at the expense of slowing down economic activities. Instead, it promotes carbon diminution through pathways such as promoting technological innovation, encouraging the modernization of the industrial framework, and promoting the transformation and upgrading of energy consumption. The baseline regression results remain robust after considering the impact of carbon dioxide measurement methods, some special cities, and other factors. Additionally, this study also finds that carbon exchanges policies have certain spillover effects and can promote the decrease in carbon emissions in neighboring areas. This study provides empirical evidence in favor of the carbon exchanges policy's potential to help China meet its "Dual Carbon" objectives of peak carbon emissions and carbon neutrality. And this study also offers significant theoretical backing for the advancement and promotion of the creation of a single, national carbon market.

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1 Introduction

Since the 20th century, the continuous expansion and development of industrial production have caused a rise in the emissions of greenhouse gases, mostly carbon dioxide, resulting in global warming. The Earth's natural ecological environment has suffered significant harm as a result of global warming, which presents a significant obstacle to the planet's sustainable growth, which is the home for human survival and development. Therefore, to mitigate global warming, controlling carbon emissions is imperative. As the largest developing country and a responsible major country, China is steadfastly pursuing a path of ecological priority and green, low-carbon growth. It sets a high value on and is dedicated to enhancing the ecological environment. In order to encourage the diminution of greenhouse gas emissions, the nation has also developed a number of low-carbon policies. One of these, the market-oriented carbon emission exchanges pilot policy (also known as the "carbon exchanges policy"), is regarded as a crucial measure that can encourage the diminution of carbon dioxide emissions and mitigate global warming (Jin et al., 2016). The seven provinces and cities in China that have seen the introduction of carbon exchanges pilot programs by the government since 2013 are Beijing, Shanghai, Tianjin, Chongqing, Hubei, Guangdong, and Shenzhen. In 2016, Fujian Province, the country's eighth carbon exchanges pilot province, formally launched carbon exchanges.

The growth of the national economy is intimately linked to carbon emissions. Although reducing industrial economic production can help lower carbon emissions, doing so at the expense of economic expansion is not a clever idea. On the other hand, pathways that enhance economic efficiency, such as improving energy utilization efficiency and the application of high and new technologies, can also contribute to carbon diminution. Examining China's economic progress throughout the previous few decades, although it has created the world-renowned "Chinese Miracle," the past economic growth in China was mainly characterized

by an "extensive" growth model. Influenced by the traditional mindset of the official promotion tournament model (Zhou, 2007), China's rapid economic growth has also been accompanied by negative issues such as overdevelopment of resources, severe ecological and environmental pollution, and low economic efficiency. The Chinese government is currently dedicated to fostering superior economic growth, which necessitates growth that is innovative and environmentally conscious. China will inevitably follow this route to attain sustainable growth. The Chinese government is currently faced with a major challenge: how to advance the "Dual Carbon" goals while maintaining superior economic growth. It is essential to the expansion and modernization of China's economy, and defining the strategy for attaining carbon diminution is the first step in resolving this issue. If carbon diminution comes at the expense of slowing down economic activities, it will lead to a decline in social welfare levels, which is not conducive to the goal of enriching the people and strengthening the country. For China's economy to grow in a high-quality manner, cutting carbon emissions through technical innovation, increasing energy use efficiency, and encouraging the modernization and transformation of energy consumption is an unavoidable path. Therefore, it is imperative to look at how the carbon exchanges policy's emission diminution mechanism affects China's "Dual Carbon" aims and quality economic development (Shao and Li, 2022).

The impact of carbon exchanges programs on cutting back on emissions has been extensively studied, with numerous studies demonstrating that such policies can significantly lower carbon emissions. For example, Using the synthetic control method, Liu et al. (2019) investigated how pilot carbon exchange policies affected emission diminution and discovered that these policies significantly decreased carbon dioxide emissions. Using a continuous difference-in-differences approach, Zeng et al. (2022) estimated the effect of carbon exchanges policies on emission diminution. Their findings demonstrated that carbon exchanges regulations

reduced carbon emission intensity in pilot areas by 9.5 percentage points. Studies have shown, meanwhile, that carbon exchanges schemes have not actually aided in the diminution of carbon emissions. For example, Zhou et al. (2019) discovered that policies pertaining to carbon exchanges did not promote carbon diminution; rather, it was the downturn in economic activity. As a result, the findings of the current studies on how carbon exchanges systems affect emission diminution are inconsistent. Research employing diverse sample sizes symbolizes that the effects of experimental carbon emission exchanges schemes on the financial operations of various organizations and areas are not uniform. Carbon diminution can be facilitated by an effective carbon emission exchanges pilot strategy that encourages technical innovation, industrial structure upgrade, and economic change. On the other hand, an ineffective carbon emission exchanges scheme may impede economic growth in addition to failing to meet the objectives of energy saving, carbon diminution, and environmental protection. Therefore, it is crucial to do additional research to determine if carbon exchanges regimes effectively promote carbon diminution and the mechanisms behind such promotion, particularly in light of the current context of the "Dual Carbon" goals and the promotion of superior economic growth.

Based on the aforementioned background and analysis, this work builds a multi-period DID method to empirically examine the carbon exchanges policy's influence on emission diminution. It treats the implementation of the pilot carbon emission exchanges policy as a quasi-natural experiment. According to the empirical findings, the pilot carbon emission exchanges policy's implementation has greatly lowered the intensity of carbon emissions. Since the parallel trend assumption is the foundation for applying the DID model, this work builds a dynamic model based on the event study approach to verify the parallel trend assumption. The findings support the validity of the parallel trend assumption. This self-selection behavior of the carbon exchanges policy may interfere with the

evaluation of its emission diminution effect in this paper, given that the selection of pilot cities for the policy may not be random but rather a thorough consideration based on local urban economic development levels and carbon emission volumes. In order to assess the impact of the carbon exchanges policy on emissions, this research also uses the Propensity Score Matching (PSM) in conjunction with the DID technique. The findings show that the carbon exchanges program has a considerable impact on emissions. The robustness of the benchmark results is tested in the robustness test section of the paper by substituting the explained variable, eliminating a few specific cities, and applying the conventional DID technique. This paper's mechanism analysis demonstrates how the carbon exchanges regime encourages carbon diminution through a variety of channels, including advancing technical innovation, modernizing urban industrial structures, and increasing energy efficiency. Furthermore, this analysis reveals that carbon exchanges regulations can encourage the diminution of carbon emissions in nearby areas and have some spillover effects. Ultimately, conclusions are reached and related policy recommendations are put out in light of the analysis presented in this study.

This paper's remaining sections are organized as follows: The overview of the literature and theoretical hypotheses are presented in the second section; the model establishing and variable explanations are described in the third section; the empirical results and analysis are provided in the fourth section; the mechanism analysis of the decrease in emissions effect of carbon transactions policy is conducted in the fifth section; and the conclusions and policy implications of the paper are presented in the final section.

2 Literature Review and Theoretical Hypotheses

2.1 Literature Review

The notion of exchanges pollution rights was first introduced by economists in the 1990s and is the basis for carbon exchanges policy, a market-oriented low-carbon policy. It was first used for atmospheric and pollution control in the United States. The first carbon exchanges pilot in Shenzhen was introduced in June 2013, which is when the market for carbon exchanges in China initially gained traction. Following that, seven more provinces and cities—Tianjin, Beijing, Guangdong, Shanghai, Chongqing, Hubei, and Fujian—also launched trial programs for carbon emission exchanges. China's "Dual Carbon" ambitions and the country's superior economic growth greatly depend on how well the carbon exchanges policy is implemented in terms of encouraging carbon diminution.

Despite a large amount of research, there is still disagreement over how China's carbon exchanges program reduces emissions. According to certain research, carbon intensity and carbon emissions can be successfully decreased by carbon exchanges programs. By encouraging increases in energy efficiency, Zhang et al. (2017), for example, examined the emission diminution effect of carbon exchanges policies using panel data from 30 Chinese provinces. Their findings suggested that carbon exchanges policies can successfully cut carbon emissions. Carbon exchanges policies can lower carbon dioxide emissions from the industrial sector, according to Zhang et al.'s (2020) evaluation of the influence of such policies on emission diminution using an optimization model based on the DEA method. In order to empirically test the emission diminution effect of carbon exchanges policies, Wu et al. (2021) and Xuan et al. (2020) used the carrying out of carbon emission exchanges pilot policies as a quasi-natural experiment condition and developed a difference-in-differences method. The findings indicated that carbon exchanges policies promoted carbon diminution. Other research, however, symbolizes that carbon diminution has not actually been aided

by carbon exchanges policies. For instance, Zhou et al. (2019) discovered that rather than carbon exchanges policies, the slowdown in economic activity was what encouraged carbon diminution. It is therefore necessary to provide more solid evidence on whether carbon exchanges policies effectively lower emissions because current research on the emission diminution effect of carbon exchanges policies may yield inconsistent conclusions based on different research subjects and methodological choices.

The results of studies on the impact of China's carbon exchanges scheme on emission diminution generally differ. This paper's marginal contribution to previous research is that it assesses the impact of carbon exchanges programs on emission diminution by utilizing more precise city-level carbon emission data. This work constructs a multi-period Difference-in-Differences (DID) model and uses it to experimentally examine the emission diminution effect and the mechanism of the diminution path. It treats the implementation of the carbon emission exchanges pilot policy as a quasi-natural experiment. The majority of the carbon emission data used in this research comes from provincial levels. Although there are a few studies at the city level based on the city statistical yearbook, the data may have significant errors (Wu, et al., 2021). Thus, for empirical testing, this research employs the carbon emission data fitted and estimated by Chen et al. (2020) based on nighttime light data. Based on the strong association between economic activity and data on nighttime light brightness, this data fits the data on carbon emissions of every Chinese county quite well and inverts them. Since the city level is the focus of this paper's research, statistics on city-level carbon emissions can be obtained by adding up the county-level emissions. Furthermore, for robustness testing, this paper additionally makes use of the carbon dioxide emission inventory data for 47 economic sectors that Shan et al. (2022) gathered. Furthermore, in contrast to earlier research, which mostly employed the conventional DID methodology for assessment, we employed a multi-period

Difference-in-Differences approach to estimate the emission diminution effect of carbon exchanges policies (Deng, 2016; Zeng et al., 2022). The multi-period DID, in contrast to the normal DID, is able to capture the varied treatment impacts of enacting carbon exchanges regimes at various points in time. As a result, the causal effects calculated using the multi-period DID are more impartial and precise.

2.2 Theoretical Hypotheses

One instrument for market-driven environmental regulation is the carbon exchanges scheme. In contrast to industrialized nations in Europe and America, China's carbon market was established later and has several notable problems, including outdated laws and ineffective market mechanisms (Zhao et al., 2016). The majority of current research on how carbon exchanges policies affect emission diminutions holds that carbon markets can encourage the diminution of carbon dioxide emissions. For instance, Xuan et al. (2020) built a difference-in-differences method to empirically test the emission diminution effect of carbon exchanges policies, and the results showed that carbon exchanges policies promoted carbon diminution. They used the carrying out of carbon emission exchanges pilot policies as a quasi-natural experiment condition. Liu and Zhang (2017) investigated the connection between corporate green technology innovation and the adoption of carbon pricing regulations against the backdrop of China's carbon exchanges policy. The findings of the study suggest that corporate green technical innovation has been stimulated by the introduction of carbon exchanges rules. According to Zhou and Qin (2020), carbon exchanges policies have the potential to facilitate the modernization of the industrial structure and lead to the establishment of a low-carbon economy. corporations are encouraged to conduct technical innovation and research and development by the introduction of carbon exchanges rules. By reducing carbon emissions and manufacturing costs, corporations may increase market earnings through technological research and development. As a result, this study suggests testing the following theories:

Hypothesis 1: Policies that entail carbon exchanges have the potential to significantly lower emissions by encouraging the decrease in the release of carbon extent.

How can carbon exchanges programs encourage the diminution of carbon emissions? In order to lower carbon emissions, an effective carbon exchanges strategy should encourage technical advancement, industrial restructuring, and economic change. On the other hand, an ineffective carbon exchanges scheme may impede economic growth in addition to failing to meet the objectives of energy saving, carbon diminution, and environmental preservation. Thus, for high-quality economic growth, the mechanism study of the emission diminution effect of carbon exchanges policies is crucial. First, citing previously published research, carbon exchanges regulations have the potential to foster technological innovation. A market-oriented low-carbon strategy that can limit the manufacturing activities of businesses with low production efficiency and raise their costs is carbon exchanges. As a result, it will compel businesses to do technical R&D, lower their carbon footprints, and ultimately produce technological innovation. Second, the modernization of the industrial structure may be encouraged by carbon exchanges rules. According to Li et al. (2021), the creation of carbon exchanges markets can encourage the modernization of the local industrial structure, which will lower carbon dioxide emissions and enhance the quality of air in cities. Last but not least, the objective of carbon exchanges policies is to lower carbon emissions. By encouraging businesses to switch from conventional to renewable energy sources, increase energy usage efficiency, and accomplish the transformation and upgrading of energy consumption, these policies may help lower carbon emissions. In light of the aforementioned study, this research suggests testing the following hypothesis:

Hypothesis 2: Carbon exchanges policies promote carbon diminution through pathways such as promoting technological innovation, the structure of industry upgrading, and the transformation and modernizing consumption of energy, rather than by slowing down economic activities.

3 Identification Strategy and Variable Description

3.1 Identification Strategy

This research analyzes the implementation of the carbon exchanges policy in eight pilot provinces as a quasi-natural experiment to determine the emission diminution effect of the policy. This paper constructs the following multi-period Difference-in-Differences (DID) model, taking into account the staggered start times of the carbon exchanges initiatives across these eight pilot regions (Shenzhen City, Beijing City, Tianjin City, Shanghai City, and Guangdong Province initiated in 2013, Hubei Province and Chongqing City in 2014, and Fujian Province in 2016):

$$y_{it} = \beta_0 + \beta_1 treat_i \times post_{it} + \delta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (1)$$

In equation (1)， i symbolizes the city, t symbolizes the year; y_{it} is the dependent variable, indicating the log of the carbon intensity of city *i* in year *t*; $treat_i$ is an indicator for the treatment group, where $treat_i = 1$ if city *i* is a pilot city for carbon exchanges, and $treat_i = 0$ otherwise; $post_{it}$ symbolizes the implementation of the carbon exchanges policy, where $post_{it} = 1$ for the year *t* and subsequent years that city i adopts the carbon exchanges program in year t, and $post_{it} = 0$ otherwise; $controls_{it}$ represents the time-varying control variables at the city level; λ_i is the city fixed effect; γ_t is the time fixed effect; ε_{it} is the stochastic disturbance term. Considering that the error variances of different individuals may vary, which means that the homoscedasticity assumed in the classic linear model is not satisfied. Therefore, this paper uses robust standard errors to address the issue of heteroscedasticity.

Using a multi-period DID method to evaluate a policy implemented at different time points offers several advantages. On one hand, Multi-period DID allows us to capture the dynamic effects of a policy over time, providing insights

into how the impact evolves rather than just a snapshot at a single point in time. On the other hand, compared to the standard Difference-in-Differences (DID) approach, the multi-period DID can yield more accurate and unbiased estimates of the policy effects. In the robustness check section of this paper, the carbon exchanges policy's impact on emission diminution was assessed using the conventional DID approach as well.

The research period of this paper is between 2008 and 2017. The reasons for selecting the research year only up to 2017 are as follows: First, China formally established a national carbon emission exchanges scheme on December 19, 2017, which was a noteworthy first step toward using market mechanisms to control and lower greenhouse gas emissions and support green, low-carbon growth. However, this policy is nationwide, and we cannot capture its impact on carbon emissions of individual cities; therefore, using data from 2017 and beyond would interfere with the identification in this paper. Second, in 2018, China began to explore and implement the "New Energy Vehicle Carbon Quota" policy, which aims to use market mechanisms to encourage automobile manufacturers to increase the production and sales ratio of new energy vehicles (NEVs), thereby reducing carbon emissions in the transportation sector. However, it is still unclear whether each city has adopted this policy and when it was implemented; hence, using data from 2017 and afterward would also interfere with the identification in this paper. Third, the precision with which carbon emissions are measured. Though there are a few studies at the city level based on the city statistical yearbook, the data may have larger mistakes. Currently, the majority of carbon emission data utilized in research on China's carbon diminution are at the provincial level (Wu et al., 2021). In light of the strong correlation between economic activity and nighttime light brightness data, this paper uses the carbon emission data measured by Chen et al. (2020) based on nighttime light data for empirical testing, which fits well and inverts the carbon emission data of each county in China. Nevertheless, given the precision of carbon

emission measurements, we excluded years after 2017.

3.2 Variable Description

3.2.1 Dependent Variable and Core Explanatory Variable

The log of each city's annual carbon intensity is the dependent variable in this study. The ratio of carbon dioxide emissions to the actual regional GDP (gross domestic product) is known as carbon emission intensity. The county-level data estimated by Chen et al. (2020), which were fitted using data on nighttime light, are the source of the city-level carbon dioxide emission statistics. In the robustness check section, this paper employs carbon dioxide emission inventory data compiled by Shan et al. (2022) for 47 economic sectors to conduct robustness checks. Using 2006 as the base year, the actual GDP values for each city are computed for each year. The interaction term, which reflects the effect of the carbon exchanges scheme on carbon intensity, serves as the primary explanatory variable in this study. The carbon pricing regime may successfully encourage carbon diminution if this interaction term is positive and statistically significant.

3.2.2 Control Variables

A number of confounding variables that influence the determination of the emission diminution effects of carbon exchanges schemes as control variables have been chosen for this article. (1) Economic Development Level. In order to gauge the degree of urban economic development, the study used the real GDP growth rate, which was determined using 2006 as the base year, and the fixed asset investment to GDP ratio, which was decided by drawing on Liu and Zhao (2015). Industrial Structure No. 2. The ratio of employees in the secondary industry, the percentage of industrial output over a set size, and the value of secondary industry output to GDP have been selected by the study as indicators of the industrial structure of the city. (3) Level of Exposure to External Environment. The degree of a city's openness to the outside world is determined by the paper using the ratio of actual foreign capital utilized to actual GDP. According to

Copeland and Taylor's "pollution haven" theory (1994), foreign direct investment influences both local carbon emissions and economic development. (4) Digital Economy Level. The degree of the city's digital economy is gauged by the log of the number of internet broadband users and per capita spending on science and technology, according to the report. According to research by Zhao et al. (2020), lowering carbon emissions is facilitated by increasing the degree of growth of the digital economy. (5) The Financial Development Level. In particular, the total number of loans from financial institutions per person at the end of the year. (6) Economic Agglomeration Degree. The degree of urban economic agglomeration is determined by taking the log of the total population and urban population density, as selected by Wu et al. (2021) in this work. (7) Government Scale. The government's size is measured by the paper using the ratio of public budget expenditure to GDP. Whether a city can effectively carry out carbon emissions policies is related to local government spending, and at the same time, the scale of the government has an important impact on economic activities, so the scale of the government may be a potential confounding factor. (8) Level of Education. The paper selects the proportion of regular institutions of higher education students and per capita government educational expenditure to measure the level of urban education. Lucas (1988) proposed the human capital externality model, which suggests that education has externalities and can promote technological progress; the level of urban innovation affects carbon emissions. (9) Infrastructure Construction. The paper uses the per capita area of urban roads to measure the level of urban infrastructure construction. Regions with more complete infrastructure construction can more effectively promote carbon diminution and economic development through carbon exchanges policies (Shao and Li, 2022).

3.2.3 Data Sources

Chen et al. (2020) provided the city-level carbon dioxide emission statistics, which were then combined with county-level data to produce city-level carbon dioxide emissions. The city-level control variable data originate from the "China City Statistical

Yearbook." Cities in the Tibet region are not included in this paper's sample because of the severe lack of some characteristics for those cities. The final sample spans ten years, from 2008 to 2017, and consists of 281 cities. The China Emission Accounts Database (CEADs) provided the carbon dioxide emission statistics used in the robustness testing section. Furthermore, this work consistently uses data for metropolitan regions, taking into account the accuracy of the data (as cited in Lu et al., 2015).

3.2.4 Descriptive Statistics

Following data cleaning, Table 1 displays the descriptive statistics for the major variables. It can be observed that there are minor discrepancies between the carbon dioxide emissions calculated by Chen et al. (2020) and those from the China Emission Accounts Database (CEADs). This also symbolizes that there is currently a lack of a unified standard for carbon dioxide measurement, and there are certain errors between different measurement methods. Therefore, it is crucial to choose high-quality, considerably more precise carbon dioxide measurement data for assessing how carbon exchanges programs affect emission diminution. The measurement technique employed by Chen et al. (2020) is considered to have the best fitting effect currently available (Wu, 2021), offering a strong basis for determining the impact of carbon exchanges policies on emission diminution in this work. Additionally, the mean of the logarithm of carbon emission intensity for cities with the implementation of the carbon exchanges pilot policy is -4.26, with a standard deviation of 0.49; for cities without the implementation of the pilot policy, the mean is -3.81, with a standard deviation of 0.55. Assuming that there is no significant difference in the mean carbon emission intensity between cities with and without the implementation of carbon exchanges policy, is rejected at a two-sided significance level of 10%. After calculation, we can reject the null hypothesis at the two-sided 10% significance level when the sample size is greater than 46. The total sample size of this paper is 2659, which is much larger than 46. Therefore,

we can ensure that the test has adequate statistical power under the effect size and the significance level.

Table 1 Descriptive Statistics of the Main Variables

Variable	Definition	Observation	Mean	Min	Max
Lnco2_1	Log of Carbon Dioxide Emissions (in millions of tons), from Chen et al. (2020)	2659	3.068	0.818	5.441
Lnco2_2	Log of Carbon Dioxide Emissions (in millions of tons), from CEADS	2206	3.341	0.851	6.081
GDP	Actual Gross Domestic Product (in billion yuan)	2659	1737.051	64.82	25388.301
Growth	Growth Rate of Actual Gross Domestic Product (%)	2659	10.928	-31.1	384.16
Assets	Fixed Asset Investment as a Percentage of Gross Domestic Product (%)	2659	15.101	5.71	18.808
Second	Proportion of Employees in the Secondary Industry (%)	2659	46.475	3.65	85.73
Segdp	The proportion of the value added by the secondary industry in GDP	2659	49.597	13.57	90.97
Lnindus	The log value of the industrial output value above a certain scale	2659	15.759	9.941	19.584
Open	The proportion of foreign direct investment (FDI) amount in GDP	2659	29.363	0.02	311.13
Popden	Population density	2659	433.037	4.94	2648.11
Lnpop	The log value of the total population	2659	5.881	2.923	9.315
Education	Proportion of Enrolled Students in Regular Higher Education Institutions (%)	2659	209.51	0.001	38.361
Exp_edu	Government Per Capita Education Expenditure (Yuan)	2659	597.6	4.079	12538.714
Internet	Log Value of Internet Broadband Subscription Users	2659	7.454	1.609	17.762
Science	Per Capita Expenditure on Science and Technology (Yuan)	2659	111.691	.153	10481.143
Govment	Proportion of Government Fiscal Budget Expenditure in GDP	2659	2236.992	440.329	18655.703
Road	Per Capita Urban Road Area (Square Meters)	2659	11.443	0.31	108.37
Loan	Per Capita Year-End Financial Institution Loans (Ten Thousand Yuan)	2659	10.171	6.011	13.757
Patent	Log Value of Total Number of Invention Patents (Ten Thousand Pieces)	2659	-2.111	-7.824	2.809
Third	Proportion of Tertiary Industry Output Value in GDP (%)	2659	39.241	10.14	80.56
Consume	Log Value of Energy Consumption Intensity	2659	-6.554	-10.216	-4.765
Coal	Proportion of Coal in Total Energy Consumption (%)	2659	0.993	.069	2.345
R&D	Logarithmic Value of R&D (Research and Development) Internal Expenditure	268	11.887	5.694	16.750

4 Empirical Results and Analysis

4.1 Baseline Regression Results

The baseline regression results for equation (1) are shown in Table 2. While year and city fixed effects are controlled for in column (1), no control variables are included; control variables are added in columns (2) and (3), respectively, and year and city fixed effects are controlled for; column (4) displays the regression results with both control variables and city-year fixed effects included. Table 1's results show that the coefficient of the regression is negative and significantly negative at the 1% level, irrespective of the addition of control variables or the use of fixed effects for cities and years. This symbolizes that the carbon emission intensity of cities has been considerably lowered since the carbon pricing program was put into place, demonstrating a significant emission diminution effect. Therefore, Hypothesis 1 is verified and established. Additionally, the regression coefficient in column (4) indicates that, holding all other conditions constant, cities with the implementation of the carbon exchanges pilot policy have experienced a significant reduction of 6.51% in carbon intensity compared to those without the policy implementation (calculated as $(e^{-0.673}-1)\times 100\%$). The policy effect estimated in this paper is close to the assessment results in existing literature. For instance, a study by Wu et al. (2021) demonstrated that the carbon exchanges policy reduced the carbon emission intensity of cities by 8.95%. Another study by Zeng et al. (2022) showed that the carbon exchanges policy could reduce the carbon emission intensity in pilot areas by 9.5%.

Table 2 Baseline Regression Results

	(1) OLS	(2) OLS	(3) OLS	(4) OLS
Treat*Post	-0.0892***	-0.1487***	-0.1414***	-0.0673***
	(0.0059)	(0.0259)	(0.0102)	(0.0064)
Controls	No	Yes	Yes	Yes
City FE	Yes	No	Yes	Yes
Year FE	Yes	Yes	No	Yes
N	2659	2659	2659	2659
Adjust R^2	0.9799	0.4675	0.8647	0.9835

Note: (1) *, **, and *** indicate significant levels of 10%, 5%, and 1%, respectively. (2) Control variables include The real GDP growth rate, the percentage of fixed asset investment in GDP, the percentage of

secondary industry employees, the percentage of secondary industry output value in GDP, the log of above-scale industrial output value, the percentage of foreign direct investment amount in GDP, population density, the log of total population, the percentage of students enrolled in regular higher education institutions, the per capita government expenditure on education, the log of the number of internet broadband subscribers, the per capita expenditure on technological innovations, the percentage of government fiscal budgetary expenditure in GDP, per individual urban roadway area, and the per capita amount of year-end loans from financial institutions. (3) The numbers in parentheses are robust standard errors.

4.2 Parallel Trend Test

The parallel trends assumption, which states that there would not be any systematic differences in the trend of carbon intensity between the treatment and control groups if the carbon exchanges policy had not been implemented, is a prerequisite assumption for using a Difference-in-Differences (DID) model. The assumption for testing the parallel trends is typically relaxed to only require that the parallel trends assumption holds prior to the policy's implementation, as we are unable to observe the carbon intensity of the treatment group that would have occurred without the intervention after the policy's implementation—that is, the counterfactual outcome is unobservable. This work builds the following empirical model based on the event study method, adhering to the methodology of Jacobson et al. (1993) and Beck et al. (2010):

$$y_{it} = \beta_0 + \sum_{k=2008}^{2016} \beta_k treat_i \times 1(t=k) + \delta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (2)$$

In equation (2), 1(*t*=*k*) is a dummy variable that takes the value of 1 when the year is k, and 0 otherwise. In accordance with Jia's (2014) methodology, this study bases its parallel trend test on the year 2012, which was the year prior to the policy's implementation. As a result, the beta coefficient in period k symbolizes the variation in carbon intensity between the experimental and control groups in the k-th year as compared to 2012. The remaining variables in equation (2) have the same meanings as in equation (1). The parallel trend assumption is satisfied if the regression coefficients for the years prior to the start of the policy fail the significance test, indicating that there were

no systematic differences between the treatment and control groups prior to the carbon emission exchanges pilot program.

Figure 1's results from the parallel trend test show that the regression coefficients for carbon intensity prior to the carbon exchanges policy's implementation are not statistically significant, indicating that the parallel trend assumption is valid and that there were no systematic differences in the trends of carbon intensity between the intervention and control groups prior to the policy's implementation. Simultaneously, the regression coefficients pertaining to the years subsequent to the carbon exchanges policy's installation exhibit a large negative trend, signifying the policy's substantial impact on reducing emissions.

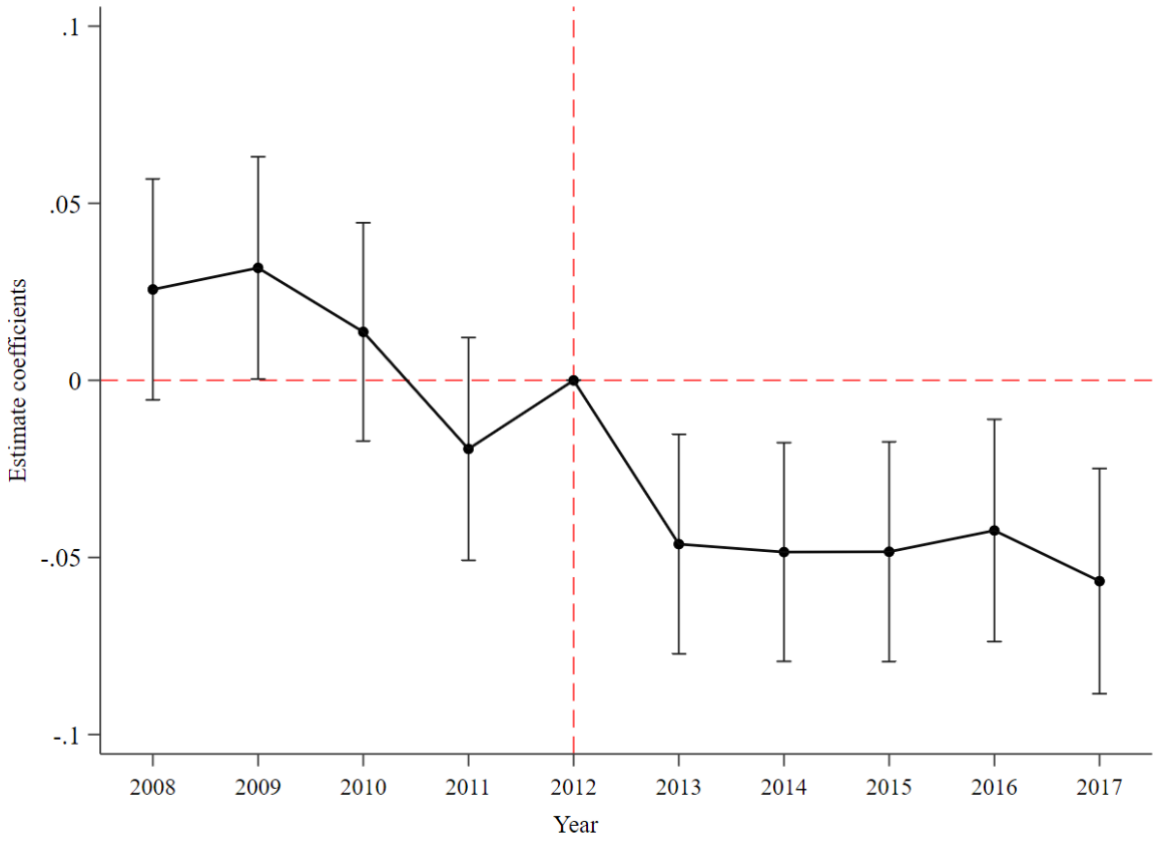


Figure 1 Emission Diminution Effect of Carbon Exchanges Policy: Parallel Trend Test

4.3 PSM-DID

This self-selection behavior of the carbon exchanges policy may interfere with the assessment of its emission diminution effect in this paper, given that the selection of pilot cities for the policy may not be random but rather based on a thorough consideration of factors such as the local city's economic development level and carbon emissions. In order to assess the impact of the carbon exchanges policy on emission diminution, this research uses Propensity Score Matching (PSM) in conjunction with the PSM-DID method to further minimize the estimation bias.

The balance test findings for a few of the factors are shown in Table 3. Table 3 shows that there are notable variations in the variables between the treatment and control groups prior to matching. Directly using Ordinary Least Squares (OLS) regression would result in bias. Therefore, this paper considers using propensity score matching to lower errors. With 'treat' as the dependent variable, this study estimates the propensity scores using a logit model, which incorporates the primary control factors into the propensity score model. After screening, the actual GDP growth rate (Growth), the ratio of fixed asset investment to GDP (Assets), the percentage of workers in the secondary industry (Second), the log of the above-scale industrial output value (Lnindus), the degree of openness (Open), and the size of the government (Government) are chosen to be included in the logit regression model because the propensity scores must satisfy the balancing property. The propensity score model is sufficiently robust, as evidenced by its passing the balancing property test. The logit regression's results are displayed in Table 3. Next, a 1:1 closest neighbor matching technique was employed by the paper for matching. Table 3 shows that there has been a considerable decrease in the imbalance of variables following matching. The covariates of the treatment and control groups are quite similar, and the standardized mean differences are close to 0.

Table 3 Covariate Balance Test Results

Logit		Balance Test						
			Mean		%	%	T Test	
Variable	Coefficient	Sample	T Group	C Group	Standard Deviation	Diminution in Standard Deviation	T	p>|T|
Growth	0.0088*	Unmatched	12.324	10.747	10.3		2.75	0.006
	(0.0053)	Matched	12.324	11.699	4.1	60.4	0.54	0.591
Assets	-0.3355***	Unmatched	15.461	15.089	32.8		6.73	0.000
	(0.0999)	Matched	15.461	15.487	-2.2	93.2	-0.34	0.734
Second	0.0165***	Unmatched	52.634	45.662	51.2		9.56	0.000
	(0.0046)	Matched	52.634	52.331	2.2	95.7	0.36	0.719
Lnindus	0.6099***	Unmatched	16.44	15.715	53.5		11.03	0.000
	(0.0971)	Matched	16.44	16.424	1.2	97.8	0.19	0.852
Open	-0.0010	Unmatched	33.771	28.502	18.6		3.66	0.000
	0.0020	Matched	33.771	34.172	-1.4	92.4	-0.20	0.839
Goverment	-0.0002***	Unmatched	1740.2	2184.9	-47.5		-8.20	0.000
	0.0001	Matched	1740.2	1700.8	4.2	91.2	0.83	0.405

Figure 2 illustrates the distribution of propensity scores between the experimental group and the control group before matching, from which it can be seen that there is a significant difference between the two groups. Figure 3, on the other hand, shows the distribution of propensity scores between the experimental group and the control group after matching. This figure indicates that the distributions of propensity scores for the experimental and control groups are almost overlapping after matching. This suggests that the use of propensity score matching has made the experimental and control groups more similar, thereby enhancing the estimation efficiency of the DID approach.

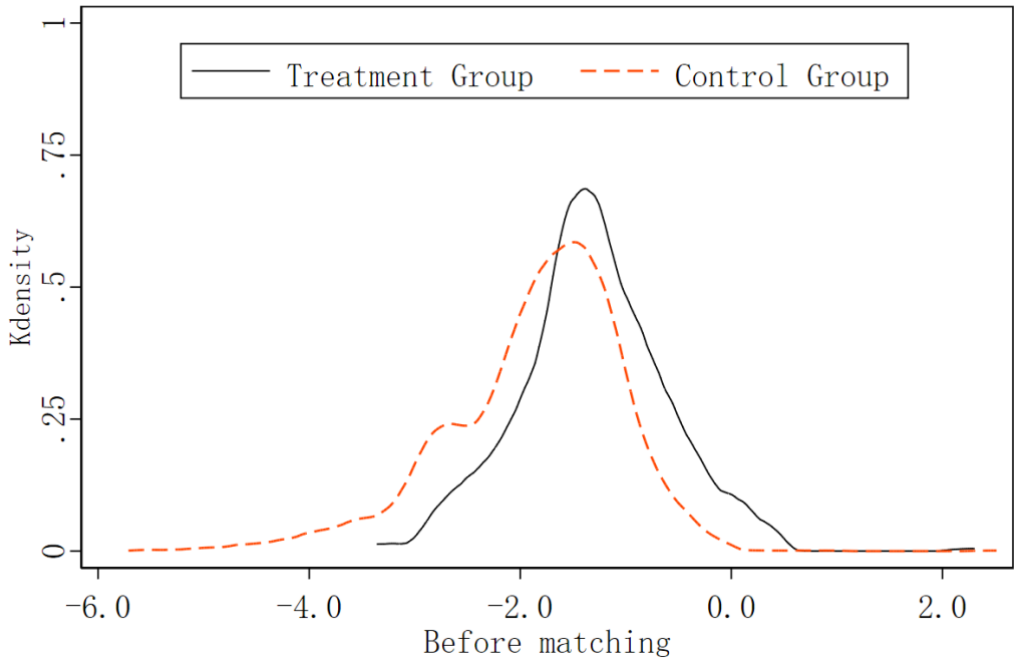


Figure 2 The distribution of propensity scores between the treatment group and the control group before matching

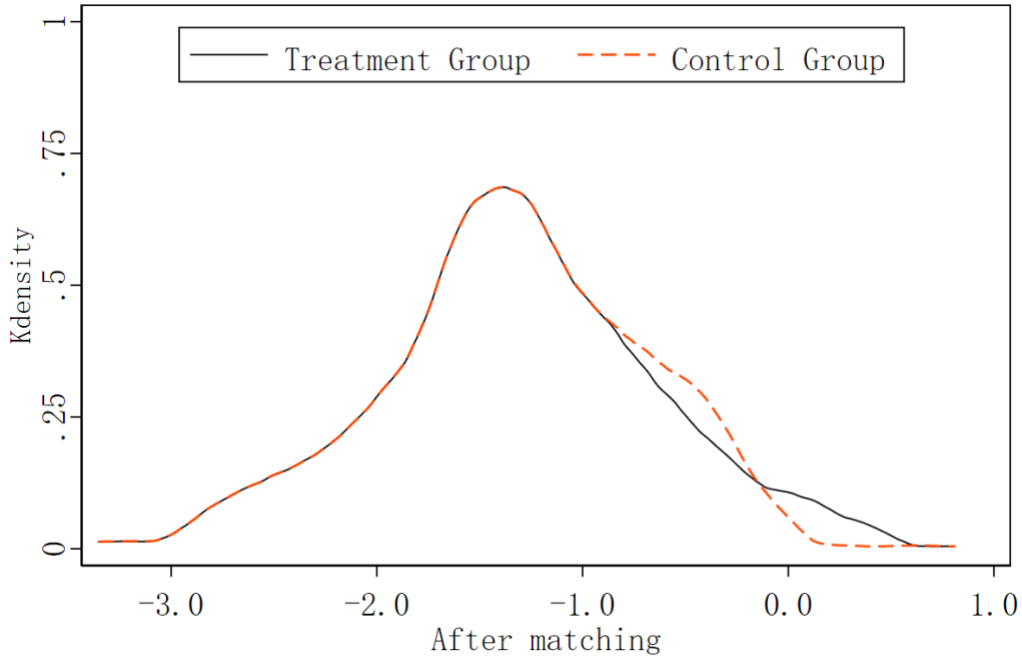


Figure 3 The distribution of propensity scores between the treatment group and the control group after matching

The covariate distribution for the matched samples is very comparable, almost like a fully randomized experiment. Thus, the emission diminution effect of the carbon exchanges policy is directly estimated in this study using a non-parametric method, and

the estimation results are shown in Table 4. According to Table 4, there are 46 treatment groups out of 920 properly matched samples, and the average treatment effect on the treated (ATT) is -0.272. This shows that the carbon exchanges policy has a significant emission diminution effect because the pilot cities that are implementing it have reduced their carbon intensity by 23.81% (exp(-0.272) - 1) compared to non-pilot cities. It is statistically significant at the 1% level (-8.480 < -1.96). This further verifies the establishment of Hypothesis 1.

Table 4 PSM-DID Estimation Results

Variable	Sample	N	Treated	Controls	Difference	S.E.	T-stat
y	Unmatched	1739	-4.258	-3.845	-0.412	0.026	-15.690
	ATT	920	-4.258	-3.986	-0.272	0.032	-8.480

4.4 Robustness Tests

4.4.1 Altering the Approach to Carbon Dioxide Calculation

This paper used the carbon dioxide emission inventory data compiled by Shan et al. (2022) for 47 economic sectors for regression analysis because there are differences in the results of urban carbon dioxide emissions calculated using other methods and to test the robustness of the baseline regression results. Table 5's column (2) displays the regression's findings. The results indicate that the carbon dealing policy has a large emission diminution effect and that its implementation greatly lowered carbon intensity at the 1% level. The baseline regression results are also robust.

4.4.2 Excluding Some Special Cities

Certain specific cities may have an influence on the carbon exchanges policy's ability to lower emissions because of the wide variations in market maturity and economic development levels throughout cities. Thus, by excluding a few specific cities, this research investigates the robustness of the baseline regression results. Chongqing is firstly left out. As the only carbon exchanges policy pilot city in the western region, where there are considerable regional economic development disparities and the economy

is relatively underdeveloped, Chongqing might interfere with the identification of the carbon exchanges policy's emission diminution effect in this paper. The regression findings in Column (3) of Table 5 are presented after Chongqing has been excluded. These results do not differ significantly from the baseline, suggesting that Chongqing's inclusion has no effect on the causal identification in this work. Second, Shanghai and Beijing are not included. Beijing and Shanghai, the country's two most economically advanced cities, have implemented the carbon exchanges strategy in addition to other low-carbon emission diminution efforts. Therefore, these two most developed cities may be responsible for the carbon exchanges policy's notable influence on reducing emissions. As a result, these two cities are not included in the robustness testing of this article. There is less reason to be concerned that the emission diminution effect of the carbon exchanges policy could be attributed to Beijing and Shanghai, as the results in column (4) of Table 5 demonstrate that the emission diminution effect of the policy after excluding these two cities is not significantly different from the baseline regression results. Third, exclusions apply to low-carbon pilot cities. The National Development and Reform Commission (NDRC) designated the first batch of low-carbon pilot provinces and cities, including Guangdong and Tianjin, as early as 2010 in an effort to change the mode of economic development and accomplish a low-carbon economic transition. The second batch of low-carbon pilot cities was subsequently established in 2012, involving 29 cities and provinces, including Shanghai, Beijing, and Hainan. In 2017, the third group of pilot cities was founded. The low-carbon pilot program may complicate the evaluation of the carbon exchanges policy's impact on reducing emissions because the study spans the years 2008 to 2017. As a result, the regression analysis in this work does not include cities that were named low-carbon pilot cities between 2008 and 2017. The baseline regression results are resilient, as evidenced by the fact that the carbon exchanges policy continues to have a large emission diminution effect even after removing the low-carbon pilot cities, as shown by the regression results in column (5) of Table 5.

4.4.3 Standard DID

Considering the differences in the adapting timing of the carbon exchanges policy across various cities, this paper constructs a multi-period DID model. However, some literature (e.g., Deng, 2016; Zeng et al., 2022) suggests that the provinces and cities implementing the carbon exchanges policy had already completed their preparatory work by 2013, hence setting the policy implementation year as 2013. Additionally, due to the later start and voluntary nature of the carbon exchanges in Fujian Province, it is not included in the sample. in order to assess the impact of the carbon exchanges strategy on emission diminution, this research also builds the following conventional DID model:

$$y_{it} = \beta_0 + \beta_1 treat_i \times post_t + \delta controls_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (3)$$

The subscript "post" in equation (3), which symbolizes the policy implementation period, does not contain a letter "i" like it does in equation (1). This symbolizes that the start date of the carbon exchanges policy is uniformly set in 2013 for all cities. Every other variable has the same significance as it does in equation (1). The regression findings are shown in Column (6) of Table 5, where the regression coefficient is -0.0487 and significant at the 1% level. These results suggest that the carbon exchanges regime continues to have a significant impact on reducing emissions. This paper's baseline regression results are solid.

Table 5 Results of Robustness Checks

	Baseline results	Carbon Emissions Calculated by CEADs	Excluding the City of Chongqing	Excluding the Cities of Shanghai and Beijing	Excluding Low-Carbon Pilot Cities	Standard DID
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
Treat*Post	-0.0673***	-0.0328*	-0.0643***	-0.0625***	-0.0661***	-0.0643***
	(0.0064)	(0.0188)	(0.0063)	(0.0064)	(0.0071)	(0.0065)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	2659	2140	2649	2639	2190	2659
Adjust R^2	0.9835	0.9592	0.9836	0.9835	0.9811	0.9835

Note: (1) *, **, and *** indicate significant levels of 10%, 5%, and 1%, respectively. (2) Control variables include The real GDP growth rate, the percentage of fixed asset investment in GDP, the percentage of secondary industry employees, the percentage of secondary industry output value in GDP, the log of above-scale industrial output value, the percentage of foreign direct investment amount in GDP, population density, the log of total population, the percentage of students enrolled in regular higher education institutions, the per capita government expenditure on education, the log of the number of internet broadband subscribers, the per capita expenditure on technological innovations, the percentage of government fiscal budgetary expenditure in GDP, per individual urban roadway area, and the per capita amount of year-end loans from financial institutions. (3) The numbers in parentheses are robust standard errors.

4.4.4 Placebo Test

This study uses the placebo test approach, as described by Chetty et al. (2009) and Shi et al. (2018), to simulate a treatment group in order to verify the robustness of the baseline regression results. Specifically, since there are 46 pilot cities implementing the carbon exchanges policy and 235 non-pilot cities in the sample used in this paper, 46 cities are randomly selected from the 235 non-pilot cities to serve as fictitious treatment cities. Then, by estimating equation (1), a policy effect regression coefficient is obtained. After repeating this operation 500 times, a distribution of the causal effect coefficients after the fictitious treatment group is obtained, as shown in Figure 4. Following the imaginary treatment group, the mean of the policy causal effect is zero, a considerable distance from the vertical red solid line. The estimated coefficient of the benchmark regression model under the effects of the actual carbon exchanges scheme is represented by the vertical red solid line. Consequently, the robust baseline regression results allay worries that other unobserved

confounding factors might influence the causal identification in this paper. The placebo test shows that the fictitious treatment group does not significantly promote the diminution of carbon intensity after the carbon exchanges policy.

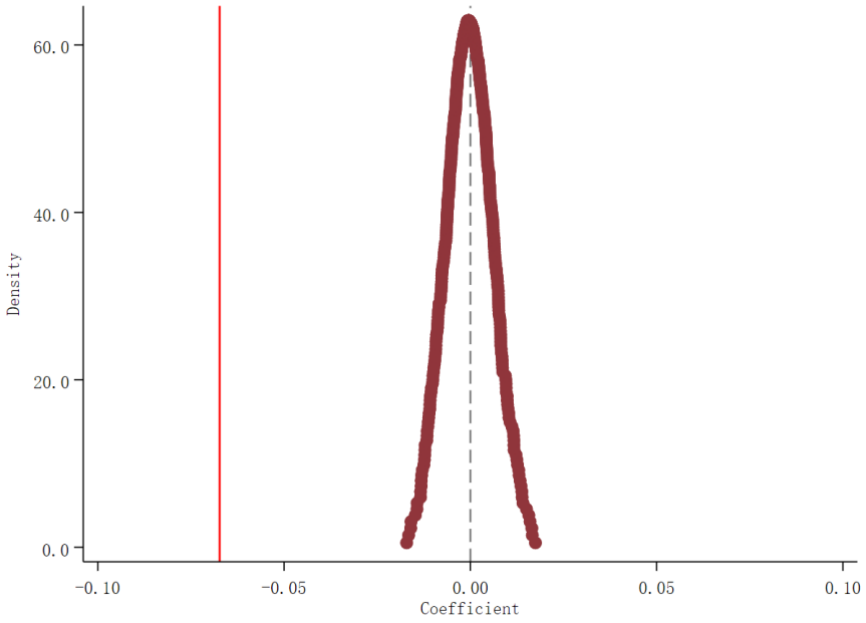


Figure 4 The Distribution of Regression Coefficients in Placebo Tests

5 Mechanism Analysis

As per the preceding sections' theoretical analysis and literature assessment, the carbon exchanges program has the possibility to lower carbon emissions by slowing down economic activities. Conversely, it can also encourage carbon diminution through various avenues, like advancing technical innovation, upgrading the industrial structure, and increasing energy efficiency—the last of which is a necessary step toward achieving superior economic growth. Therefore, this study will perform a mechanism analysis of the emission diminution effect based on equation (1) in order to assess whether the carbon exchanges policy indirectly promotes superior economic growth through its emission diminution paths.

First, this paper selects the log of real GDP as the dependent variable to examine whether the carbon exchange regime promotes carbon reduction by inhibiting economic activity. The regression analysis in column (1) of Table 6's results shows that the carbon exchange policies' Implementing the program significantly accelerates the rise of urban actual GDP, demonstrating that it has no negative effects on local economic activity.

Secondly, in order to ascertain whether the carbon exchange plan lowers carbon emissions by promoting technical innovation, this study also looks at the total number of invention patents granted at the city level and the log of R&D investment, which both indicate the degree of urban innovation. The regression results in column (2), where the dependent variable is the log of the total number of innovation patents, show that the implementation of the carbon exchange program considerably boosts the overall number of city-level invention patents at the 1% significance level. The carbon exchange program incentivizes businesses to do research and development as well as innovation because it is a market-oriented strategy. This reduces carbon emissions and saves money by fostering technological innovation. The regression results show that the implementation of the carbon emissions regime significantly increases R&D investment, with R&D investment being the dependent variable in column (3). Research and development technology spillovers significantly reduce carbon emissions, according to an Jiao et al. (2018) study.

Third, in order to evaluate whether the carbon exchange policy promotes carbon diminution by boosting the upgrading of the industrial structure, this article then selects the GDP percentage of the tertiary industry's output value as a proxy variable for the upgrading of the industrial structure. The regression findings in Table 6's column (4) demonstrate how the carbon exchange policy significantly increases the production value of the tertiary industry relative to GDP, which in turn promotes the upgrading of the industrial structure. Studies by Wang and Wang (2019) and Li et al. (2021) show that altering the industrial structure can effectively reduce carbon emissions.

Lastly, in order to determine whether the carbon exchange policy enhances carbon reduction by promoting the transformation and upgrading of energy consumption, this article ultimately selects energy consumption intensity and the percentage of coal consumption to evaluate the transformation and upgrading of energy consumption. The regression results in Table 6's column (5) show that the implementation of the carbon exchange regime significantly reduces urban energy consumption intensity, reducing carbon emissions at the source. The regression findings in column (6) indicate a notable reduction in the percentage of coal utilization. Since coal is China's primary energy source (Zhang et al., 2019), achieving the "Dual Carbon" targets will be hampered by it. The usage of conventional energy is wasteful and produces a large amount of carbon dioxide. China's energy consumption is currently shifting away from fossil fuels and toward renewable energy sources, as seen by the country's dropping coal use share. The carbon exchange scheme not only significantly reduces energy intensity but also promotes modernization and transformation of energy use. The carbon exchange policy does not impede economic growth, as the mechanism analysis above demonstrates. Rather, it encourages carbon reduction through means such as technical innovation, upgrading of industrial structures, and transformation and upgrading of energy use. The policy on carbon exchanges may indirectly promote better economic development by lowering emissions. In other words, Hypothesis 2 is proven.

Table 6 Results of Mechanism Analysis

	The log of real GDP	The number of patents	The log of R&D	Share of GDP by the tertiary sector	The log of energy consumption intensity	Proportion of coal in total energy consumption
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
Treat*Post	0.0133***	0.2659***	0.3169**	0.0095**	-0.0503***	-0.0712***
	(0.0040)	(0.0818)	(0.1286)	(0.0040)	(0.0053)	(0.0062)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	No	No	Yes	Yes
Year FE	Yes	Yes	No	Yes	Yes	Yes
N	2659	2659	245	2659	2659	2659
Adjust R^2	0.9977	0.8861	0.7374	0.7350	0.9951	0.9425

Note: (1) *, **, and *** indicate significant levels of 10%, 5%, and 1%, respectively. (2) Control variables include The real GDP growth rate, the percentage of fixed asset investment in GDP, the percentage of secondary industry employees, the percentage of secondary industry output value in GDP, the log of above-scale industrial output value, the percentage of foreign direct investment amount in GDP, population density, the log of total population, the percentage of students enrolled in regular higher education institutions, the per capita government expenditure on education, the log of the number of internet broadband subscribers, the per capita expenditure on technological innovations, the percentage of government fiscal budgetary expenditure in GDP, per individual urban roadway area, and the per capita amount of year-end loans from financial institutions. (3) The numbers in parentheses are robust standard errors.

6 Further Analysis: The Spillover Effects of Carbon Exchanges Policies

This study also investigates the indirect consequences of carbon exchanges regulations. Provinces that have adopted carbon exchanges policies but have not yet put the regulations into effect themselves are specifically classified as the experimental group, which includes the cities under their purview. The control group, on the other hand, consists of the cities under the jurisdiction of provinces that have neither enacted carbon exchanges laws nor are close to those that have. Next, a regression model that is exactly the same as Equation (1) is created, and Table 7 displays the regression findings. Of them, Column (1) has a regression coefficient that is substantially negative at the 1% level and does not include control variables or fixed effects. We included city fixed effects in Column (2) because it is possible that unobserved, time-invariant characteristics at the city level could influence the identification of this paper. Additionally, the regression

coefficient is significantly negative at the 1% level. The regression coefficient in Column (3), which also contains time-varying city-level control variables, is still strongly negative, suggesting that carbon exchanges schemes have spillover effects. In other words, carbon exchanges programs have the potential to both greatly cut carbon emissions in the cities where they are implemented and to encourage diminutions in carbon emissions in nearby cities where they are not. Column (4) takes into account additional unobserved variables that vary over time but not between cities. The regression coefficient is still negative even if it is not statistically significant, indicating that there may still be some spillover effects from carbon exchanges policies.

Table 7 Spillover Effects of Carbon Exchanges Policies

	(1) OLS	(2) OLS	(3) OLS	(4) OLS
Treat*Post	-0.2223***	-0.3085***	-0.0694***	-0.0017
	(0.0226)	(0.0120)	(0.0125)	(0.0095)
Controls	No	No	Yes	Yes
City FE	No	Yes	Yes	Yes
Year FE	No	No	No	Yes
N	2356	2356	2203	2203
Adjust R^2	0.0410	0.8653	0.9610	0.9810

Note: (1) *, **, and *** indicate significant levels of 10%, 5%, and 1%, respectively. (2) Control variables include The real GDP growth rate, the percentage of fixed asset investment in GDP, the percentage of secondary industry employees, the percentage of secondary industry output value in GDP, the log of above-scale industrial output value, the percentage of foreign direct investment amount in GDP, population density, the log of total population, the percentage of students enrolled in regular higher education institutions, the per capita government expenditure on education, the log of the number of internet broadband subscribers, the per capita expenditure on technological innovations, the percentage of government fiscal budgetary expenditure in GDP, per individual urban roadway area, and the per capita amount of year-end loans from financial institutions. (3) The numbers in parentheses are robust standard errors.

7 Conclusions and Policy Implications

This research analyzes the implementation of the carbon changes policy as a quasi-natural experiment and evaluates the policy's effect on lowering emissions by developing a multi-period Difference-in-Differences (DID) model using panel data from 281 cities across a ten-year period from 2008 to 2017. The empirical results show that the implementation of the carbon exchange system has resulted in a significant reduction in

the intensity of urban carbon emissions, demonstrating a major emission diminution effect. The results of the parallel trend test demonstrate that there were no appreciable differences in the trend of carbon emission intensity between the treatment and control groups prior to the policy's adoption, proving the validity of the parallel trends predicate of the DID approach. Predisposition Index Another way to evaluate the carbon exchange program's effect on emission reduction is to use matching in conjunction with DID (PSM-DID). The outcomes demonstrate that the program considerably lowers emissions. This paper uses a variety of techniques to assess the robustness check, including changing the method used to measure carbon dioxide, eliminating certain cities, using the traditional DID approach, and conducting placebo tests. The final results show how reliable the empirical findings in this work are. The mechanism analysis in this research demonstrates that, rather than stifling economic activity, the carbon exchange policy encourages carbon reduction through paths such as technological innovation, industrial structure upgrading, and energy consumption upgrading. This analysis also shows that carbon exchange policies have some spillover effects and can promote a reduction in carbon emissions in neighboring areas. The study's conclusions have important policy implications for China's progress toward achieving its "Dual Carbon" goals and for the country's superior economic growth. First, after analyzing the results of carbon exchange pilot projects, promote and strengthen the creation of a single national carbon market.

The study's findings suggest that the carbon exchanges scheme can both considerably lower carbon emission intensity and have a major impact on lowering emissions. For the "Dual Carbon" goals to be advanced and realized, the creation of a single national carbon market is crucial. However, because of its recent establishment, the unified national carbon market is still in its infancy and need more promotion and development. Thus, it is feasible to encourage and enhance the development of a single national carbon market by utilizing the knowledge gained from carbon exchanges pilot programs. Second, the government ought to proactively implement supplementary measures alongside the carbon emission exchanges pilot programs to encourage

sustainable economic growth and enable the mitigation of carbon emissions. To encourage carbon diminution, the government could, for instance, lower taxes or offer subsidies to high-tech businesses that actively participate in carbon exchanges, encourage businesses to innovate in green technologies, support business industrial structure upgrades, and implement other supportive policies that complement the carbon emission exchanges policy. Furthermore, the research discussed in this paper offers useful guidance on how to minimize carbon emissions for nations that have not yet created a carbon exchanges market. The majority of nations still rely on environmental regulations to deal with the problem of carbon emissions today. But as China's experience shows, market exchanges systems are also a practical means of addressing the issue of carbon emissions.

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