"Reward or Regulation?" - Carbon Emission Reduction Effects of Green Fiscal Policy

Shiyu Zhang[1, a]

[1]School of Economics, Xiamen University, Xiamen 361005, China

[a]zshiyu0122@163.com

Abstract. This paper assesses the carbon reduction effects of government green fiscal policy by focusing on the construction of "comprehensive demonstration cities for energy conservation and emission reduction". The study employs staggered Difference-in-Differences (DID) and Two-Stage DID to measure the carbon reduction effect, and the heterogeneity in the construction of three batches of demonstration cities is taken into consideration. The results indicate that the construction of demonstration cities significantly reduces local carbon emission intensity and per capita carbon emissions, mainly due to the improvement of energy efficiency. Overall, this study offers valuable insights for the development of effective green fiscal policies targeting energy conservation and emission reduction effect. It provides valuable insights for achieving green and low-carbon development by promoting mutual interactions between environmental protection and economic growth in the future.

Keywords: carbon emission reduction; green fiscal policy; "National Comprehensive Demonstration City of Energy Saving and Emission Reduction Fiscal Policy"; staggered DID

1.Introduction

On April 21, 2023, the World Meteorological Organization released the "2022 Global Climate Status Report". The report analyzed key climate indicators and indicated that although the La Niña event temporarily slowed down the trend of global temperature rise, it did not reverse the long-term trend of global warming. In the context of global climate change, achieving a low-carbon economy transition is an inevitable choice for sustainable development. Chinese President Xi Jinping emphasized the importance of a healthy ecological environment as the most equitable public good and the most inclusive welfare in his statement. At the 75th session of the United Nations General Assembly, China made a solemn commitment to increase its voluntary contributions, adopt more effective policies and measures, strive to peak carbon dioxide emissions before 2030, and strive to achieve carbon neutrality by 2060. These statements indicate that the low-carbon economy transition is not only crucial for China to adapt to the new normal of economic development but also important for making progress in both economic development and environmental protection.

China's economy has entered a phase of high-quality development, which focuses on promoting economic and social development in line with economic development laws. This is a necessary requirement for maintaining sustainable and healthy economic growth. Green transformation is the key to achieving high-quality development, requiring the abandonment of traditional high-energy consumption and high-emission development models, and instead focusing on harmony between humans and the natural environment. We need to build an industrial structure that is high-tech, low-resource consumption, and low environmental pollution to enhance the green level of the economy, reduce resource and environmental costs of development, and promote clean and environmentally safe development.

Reducing carbon emissions is crucial for achieving the dual carbon goals. In 2011, the Ministry of Finance and the National Development and Reform Commission launched a pilot project called the "National Comprehensive Demonstration Financial Policy for Energy Conservation and Emission Reduction" as part of the energy-saving and emission reduction policies during the 12th Five-Year Plan period. The first batch of eight cities, including Beijing, Shenzhen, Chongqing, and Hangzhou, were designated as demonstration cities. This was followed by the second batch of 10 demonstration cities and the third batch of 12 pilot cities in 2013 and 2014, respectively, totaling 30 pilot cities. The pilot cities were urged to accelerate institutional and mechanism innovation as driving forces. The comprehensive demonstration of urban energy conservation and emission reduction should cover low-carbon industries, clean transportation, green buildings, intensive services, major pollutant reduction, and large-scale utilization of renewable energy. The pilot cities implemented three-year projects on energy conservation and emission reduction and accelerated the construction of resource-efficient and environmentally friendly societies.

As a fiscal policy carried out during the 12th five-year Plan period, it is committed to promoting energy conservation and emission reduction, economic restructuring and the transformation of the mode of economic development, having both financial incentive effect and attraction effect. For incentive affect, during the pilot period, the central finance gives demonstration cities a comprehensive incentive fund of 400 million to 600 million yuan every year according to the type of the city, and the provincial government and the government at the same level where the demonstration city is located should also arrange special funds for the comprehensive demonstration work of energy conservation and emission reduction. What's more, the policies for energy conservation and emission reduction and the development of renewable energy should be tilted to demonstration cities through the integration of financial funds and integrated fiscal policies to promote the smooth development of energy saving and emission reduction in demonstration cities. For attraction affect, since the list of the second and third batch of model cities is selected through city declaration, both model cities and non-model cities will be attracted by the additional financial incentives allocated by the Ministry of Finance.

The structure of this paper is as follows: Section 2 provides a literature review and research hypotheses, Section 3 outlines the empirical strategy and data, Section 4 presents empirical analysis, Section 5 includes mechanism analysis, and finally, Section 6 presents conclusions.

2. Literature review and research hypotheses

2.1 Literature review

The development of green and low-carbon economies has led to constant innovation and development of tools for energy conservation and emission reduction. In the early stages, China primarily used imperative environmental regulation tools to promote energy conservation and emission reduction. However, with market-oriented reforms, market-based environmental regulation tools, such as pollution permit trading and carbon trading, have emerged. Research on market-based tools mostly focuses on pollution permit trading and carbon trading. In the context of pollution permit trading, Qi Shaozhou et al. (2018) used a triple-difference method to show that the pilot policy of pollution permit trading can increase the proportion of green innovation activities by 5.4% in polluting industries in the pilot areas. Meanwhile, Shi Dan and Li Shaolin (2020) pointed out that the pollution permit trading system can significantly reduce energy consumption per unit of gross domestic product in a region and promote the improvement of green total factor energy efficiency. Regarding the impact of carbon markets on carbon emissions, numerous studies have confirmed its significant effect in reducing carbon emissions. Wu Yinyin et al. (2021) indicated that carbon markets have a significant carbon emission reduction effect, which is reflected in a significant decrease in local carbon emissions and carbon intensity without inhibiting regional economic growth.

Cities' environmental regulatory policies, proposed in order to implement climate action goals, have also become a hot topic in environmental economics. Examples include pilot low-carbon cities and comprehensive demonstration cities for fiscal policies on energy conservation and emission reduction. Similar to market-based environmental regulations, research on urban-level environmental regulatory policies focuses on their macro-level effects on energy conservation, emissions reduction, or pollution control, as well as their micro-level impact on business innovation. For instance, Song Hong et al. (2019) found that the construction of low-carbon cities can significantly reduce urban air pollution, with the reduction in corporate emissions and upgrading and innovation of the industrial structure being the main mechanisms. Xu Jia and Cui Jingbo (2020) pointed out that pilot policies of low-carbon cities can induce green technological innovation at the corporate level to some extent, and command-and-control policy tools remain the main pathway for the effectiveness of pilot policies. Zhang Bingbing et al. (2021) suggested that the implementation of pilot policies for low-carbon cities can significantly improve the overall energy efficiency level of a city.

2.2 Research hypotheses

In the 12th five-year Plan, the Chinese government included the reduction target of carbon emission intensity as a binding target, in addition to the energy intensity target. The targets set were a 16% reduction in unit energy consumption and a 17% reduction in carbon emissions per unit of GDP compared to 2010.To support the achievement of these targets, the Ministry of Finance and the National Development and Reform Commission selected a total of 30 cities in three batches starting from 2011 to carry out the "National Comprehensive Demonstration City of Energy Saving and Emission Reduction Fiscal Policy". The first batch of demonstration cities, announced on June 22, 2011, included Beijing, Shenzhen, Chongqing, Hangzhou, Changsha, Guiyang, Jilin, and Xinyu. The second batch, announced on October 18, 2013, consisted of Shijiazhuang, Tangshan, Tieling, Qiqihar, Tongling, Nanping, Jingmen, Shaoguan, Dongguan, and Tongchuan. The third batch, selected in 2014, included Tianjin, Linfen, Baotou, Xuzhou, Liaocheng, Hebi, Meizhou, Nanning, Deyang, Lanzhou, Haidong, and Urumqi. These demonstration cities are distributed across different regions, have varying urban scales and levels of economic development, and are representative, typical, and significant in demonstrating these policies.

During the pilot period, the central government provided annual incentive funds to demonstration cities, aiming to guide and support their efforts in energy conservation and emission reduction. The scale of these funds varied based on the type of city. Municipalities directly under the Central Government and urban agglomerations received 600 million yuan, cities with separate plans received 500 million yuan, and provincial capital cities and other cities received 400 million yuan each year. In addition to the central government funds, the provincial and local governments of the demonstration cities were also required to allocate special funds for urban energy conservation and emission reduction. To ensure proper implementation, each demonstration city was required to formulate a comprehensive overall plan and a three-year specific plan, which had to be submitted to the Ministry of Finance and the National Development and Reform Commission for approval. Based on the approved plans, project reviews, and work progress, the Ministry of Finance allocated funds to the demonstration cities in batches and phases. Moreover, existing policies supporting energy conservation, emission reduction, and renewable energy development gave priority to the demonstration cities.

Among the three batches of demonstration cities, the lists of the second and third batches were selected through applications and subsequent evaluations from cities. Therefore, demonstration city construction has at least two effects: first, for demonstration cities, there is an incentive effect on carbon emission reduction through financial incentives; second, for all cities, there is an attractive effect of providing special financial support funds for energy conservation and emission reduction work by the Ministry of Finance to local governments. Therefore, the policy effect of incentive funds for energy conservation and emission reduction fiscal policies can be identified through a difference-in-differences analysis. Based on this, Hypothesis 1 is proposed in this paper:

Hypothesis 1: Comprehensive demonstration work on energy conservation and emission reduction fiscal policies can significantly reduce carbon emissions in demonstration cities under the incentive effect of financial funds.

According to the "Demonstration Work Notice," the construction of an energy conservation and emission reduction pattern should be led by the government, driven by the market, with enterprises as the main body, and with the participation of the whole society. The aim is to significantly improve the energy efficiency level in industries such as manufacturing, construction, transportation, etc., promote the widespread application of low-carbon technologies, and achieve the large-scale utilization of renewable energy. Energy consumption is the primary source of carbon emissions, and based on China's current national conditions, which are rich in coal, poor in oil, short of gas, and have abundant renewable resources, the energy use pattern of coal as the main energy source will not change in the short term. Under short-term emission reduction pressure, the government may reduce carbon emissions from the supply side by reducing "energy consumption" and other measures. In the long term, improving energy efficiency is an effective way to reduce carbon emissions. Energy efficiency can reflect the technical and economic aspects of energy utilization. Improving energy efficiency helps eliminate backward production capacity and is one of the main channels for reducing carbon emissions. Therefore, Hypothesis 2 is proposed in this paper:

Hypothesis 2: "National Comprehensive Demonstration City of Energy Saving and Emission Reduction Fiscal Policy" achieve carbon emission reduction by improving energy efficiency.

3. Empirical strategy and data

3.1 Model specification and identification

Among the 281 samples in this study, a total of 29 cities were selected as comprehensive demonstration cities for energy conservation and emission reduction policies. This provides a good natural experiment, and the approval of the 29 cities' selection is divided into three phases, which is suitable for evaluating the carbon emission reduction effect of the construction of green fiscal policy demonstration cities using the staggered difference-in-difference method. The setting of the treatment group and the control group in this study comes from the list of demonstration cities publicly released by the Ministry of Finance and the National Development and Reform Commission. The 29 selected demonstration cities are used as the treatment group, and the remaining cities that were not selected are used as the control group. The announcement of the demonstration cities is divided into three batches, so there are differences in the treatment time of demonstration cities in different batches. Based on this, in order to address the endogeneity issue that may be caused by omitted variables, this study uses the staggered difference-in-difference method and controls for city fixed effects and time fixed effects in all regressions. The following model is constructed:

$$ln\ co2pergdp_{it} = \beta_0 + \beta_1 policy_{it} + \beta_2 target12 + \gamma X_{it} + \mu_i + \vartheta_t + \varepsilon_{it} \quad (1)$$

$$ln\ pco2_{it} = \beta_0 + \beta_1 policy_{it} + \beta_2 target12 + \gamma X_{it} + \mu_i + \vartheta_t + \varepsilon_{it} \quad (2)$$

In this model, $ln\ co2pergdp_{it}$ and $ln\ pco2_{it}$are the dependent variables, representing the logarithmic values of carbon dioxide emission intensity and per capita carbon dioxide emissions for city i in year t. μ_i represents the city fixed effect, ϑ_t represents the time fixed effect, and ε_{it} is the error term. X_{it} represents the control variables, which includes variables that may affect carbon emissions such as economic development level and industrial structure. $policy_{it}$ is the core explanatory variable, namely the multiple periods differencing variable, representing the dummy variable of demonstration city construction, and its coefficient β_1 measures the policy effect of demonstration city construction on carbon emissions. If β_1 is negative and significant, it indicates that low-carbon pilot city construction is conducive to reducing carbon dioxide emissions. Since the construction of demonstration cities is part of the "Twelfth Five-Year Plan" energy conservation and emission reduction policy, the policy effect during the "Twelfth Five-Year Plan" period is controlled for in the regression to eliminate interference from other energy conservation policies during the "Twelfth Five-Year Plan" period, in order to more clearly identify the carbon emission reduction effect of demonstration city construction. $target\_12$ represents the energy-saving targets of each province during the "Twelfth Five-Year Plan" period, $Post$ is a dummy variable, taking a value of 1 from 2011 to 2015 and 0 for other times. In the regression results table, target12 represents $target\_12 * Post$. Standard errors are clustered at the city level.

Due to administrative adjustments in some cities and missing data in some areas, this study excluded cities such as Lhasa, Haidong, Bijie, and Tongren from the sample.

3.2 Data and variable description

This article uses carbon dioxide emission data, nighttime light data, energy data, and corresponding economic data from 281 prefecture-level cities in China between 2003 and 2017. Carbon dioxide emission data is the main focus of this paper, following Chen et al.'s (2020) study. The research utilized a Particle Swarm Optimization-Back Propagation (PSO-BP) algorithm to estimate the carbon dioxide emissions of 2735 counties in China from 1997 to 2017 using unified DMSP/OLS and NPP/VIIRS satellite image scales. In addition, considering that vegetation has a significant ability to sequester carbon and reduce carbon dioxide emissions, this data calculated the carbon sequestration value of county-level land vegetation. The carbon dioxide emission data at the city level is aggregated from the county-level data under its jurisdiction.

The nighttime light data used in this study comes from the National Earth System Science Data Center, which has parameter attributes consistent with the NPP-VIIRS nighttime light data and similar data quality to NPP-VIIRS. In terms of temporal consistency, this is the first global 500-meter resolution new nighttime light data set that can truly reflect the temporal changes in population and light brightness at different scales.

The energy data used in this study comes from the "China Energy Statistical Yearbook" and belongs to the provincial level. Since nighttime light data can reflect the economic activities of an area, the lighting data of each province from 2003 to 2017 are fitted with the provincial energy consumption data, demonstrating a significant positive linear correlation. Therefore, according to the research of Wu et al. (2014), a linear model without intercept is used to decompose the energy consumption data of each province into city-level data based on the nighttime light data at the provincial and city levels.

This article selects economic characteristics at the city level as control variables in the model. The city-level data comes from the "China Urban Statistics Yearbook." The energy-saving target for the 12th Five-Year Plan comes from the State Council's Comprehensive Work Plan for Energy Conservation and Emission Reduction during the 12th Five-Year Plan. Since this energy-saving target belongs to the provincial level, the emission reduction target data of the province in which the city is located is used at the city level. The descriptive statistics of the selected variables are shown in Table 1:

Table1 Descriptive statistics

VARIABLES	describe	(1) Obs	(2) Mean	(3) Std.Dev.	(4) min	(5) max
popgrowthrate	Population growth rate	4,230	5.787	5.118	-16.64	40.78
secondary	The proportion of secondary industry in GDP	3,971	48.59	11.10	2.660	90.97
tertiary	The proportion of tertiary industry in GDP	3,971	36.85	8.825	8.580	85.34
company	Number of industrial enterprises above scale	4,240	967.1	1,208	3	12,055.00
energy	Energy consumption (Ten thousand tons of standard coal)	4,270	1,013	1,657	0	18,897.40
realpgdp	Real GDP per capita	3,968	24,465	21,389	77.69	361,379.30
target_12	Energy saving target of the Twelfth five-year Plan	31	16.13	1.392	10	18

4. Empirical analysis

4.1 Benchmark regression results

4.1.1 incentive affect

Table 2 reports the regression results of Model (1), where the first to fourth columns gradually add various control variables. All regression analyses control for year fixed effects and city fixed effects.

Table 2 Benchmark regression results of carbon emission intensity

VARIABLES	(1) carbon emission intensity	(2) carbon emission intensity	(3) carbon emission intensity	(4) carbon emission intensity
policy	-0.067***	-0.080***	-0.079***	-0.079***
	(0.023)	(0.024)	(0.023)	(0.023)
target12	-0.038***	-0.042***	-0.044***	-0.044***
	(0.008)	(0.008)	(0.007)	(0.007)
secondary		-0.007***	-0.001	-0.001
		(0.001)	(0.002)	(0.003)
energy		-0.000***	-0.000***	-0.000***
		(0.000)	(0.000)	(0.000)
company			-0.000	-0.000
			(0.000)	(0.000)
lrealpgdp			-0.354***	-0.354***
			(0.108)	(0.110)
popgrowthrate			0.000	0.000
			(0.001)	(0.001)
tertiary				0.000
				(0.004)
Observations	3,948	3,945	3,903	3,902
R-squared	0.953	0.956	0.964	0.964
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively; parentheses are standard errors clustered at the firm level. Without special statements, the following tables are annotated as in Table 2.

From Table 2, after controlling for city fixed effects (City) and time effects (Year), β_1 is significantly negative, indicating a decrease in carbon emission intensity for demonstration cities at a significance level of 1%. After gradually adding control variables such as secondary industry (secondary), number of industrial enterprises above designated size (company), energy consumption (energy), real per capita GDP (lrealpgdp), population growth rate (popgrowthrate), and the proportion of added value of tertiary industry to GDP (tertiary), β_1 remains significantly negative and gradually stabilizes in value. This suggests that after implementing green fiscal policies in demonstration cities, compared to non-demonstration cities, the average treatment effect estimated by the difference-in-differences regression indicates a 7.8% reduction in carbon emission intensity for demonstration cities. Therefore, Hypothesis 1 is validated, which states that the carbon emission intensity of demonstration cities significantly decreases.

Table 3 shows the regression results with per capita carbon dioxide emissions as the dependent variable, using the same methods as Model (1).

Table 3 Benchmark regression results of per capita carbon emissions

VARIABLES	(1) per capita carbon emissions	(2) per capita carbon emissions	(3) per capita carbon emissions	(4) per capita carbon emissions
policy	-0.065***	-0.058***	-0.058***	-0.056***
	(0.022)	(0.021)	(0.021)	(0.021)
target12	-0.041***	-0.046***	-0.045***	-0.046***
	(0.005)	(0.005)	(0.005)	(0.005)
secondary		0.005***	0.003**	0.006***
		(0.001)	(0.001)	(0.001)
energy		0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)
company			-0.000	-0.000
			(0.000)	(0.000)
lrealpgdp			0.137***	0.127***
			(0.044)	(0.042)
popgrowthrate			-0.001	-0.001**
			(0.001)	(0.001)
tertiary				0.005***
				(0.001)
Observations	4,212	3,940	3,903	3,902
R-squared	0.982	0.985	0.986	0.986
City FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

From Table 3, it can be seen that after controlling for year fixed effects and city fixed effects, and gradually adding control variables, β_1 is significantly negative at a significance level of 1%. This indicates a significant reduction in per capita carbon dioxide emissions for the demonstration cities. Compared to non-demonstration cities, demonstration cities showed a reduction of around 5-6% in per capita carbon dioxide emissions.

4.1.2 Attraction effect

Due to the fact that the selection of demonstration city construction in the second and third batches was based on application and subsequent selection by cities, there may be an attraction effect on emissions reduction for demonstration city construction, as cities are attracted by the special financial support. In this paper, control group cities that did not appear in any of the three batches were selected for analysis. The regression model used is as follows:

$$ln\ co2pergdp_{it} = \beta_0 + \beta_1 Post * emission2010 + \beta_2 target\_12 * Post + \gamma X_{it} + \mu_i + \varepsilon_{it} \quad (3)$$

$$ln\ pco2_{it} = \beta_0 + \beta_1 Post * emission2010 + \beta_2 target\_12 * Post + \gamma X_{it} + \mu_i + \varepsilon_{it} \quad (4)$$

Considering that there are differences in carbon emissions levels among different cities, which may affect the incentive to compete for special financial support, this paper include $emission2010$ in both equations to reflect the differences in carbon emissions levels among cities in 2010 (i.e., the period before the policy was implemented). This variable represents carbon emission intensity and per capita carbon emissions in every city in 2010. The rest of the settings remain the same as in Models (1) and (2). The regression results are shown in Table 4.

Table 4 regression results for attraction effect

VARIABLES	(1) carbon emission intensity	(2) per capita carbon emissions
$Post * emission2010$	0.006	-0.018
	(0.026)	(0.012)
target12	0.002	0.001
	(0.006)	(0.002)
Control variables	YES	YES
Observations	3,502	3,502
R-squared	0.948	0.974
City FE	YES	YES

From the regression results of Table 4, it can be seen that none of the regression coefficients are significant and their values are relatively small. This suggests that there is no significant attraction effect for demonstration city construction, and therefore no significant impact on carbon emissions for control group cities. This also indicates that the policy has no significant spillover effect, further demonstrating the robustness of the causal identification of the incentive effect.

4.2 Parallel trend test

The key premise of the difference-in-differences method is that the experimental group and control group satisfy the parallel trend assumption, meaning that before the implementation of the "National Comprehensive Demonstration City of Energy Saving and Emission Reduction Fiscal Policy", the trends in carbon emission intensity and per capita carbon dioxide emissions remained relatively stable.

In this paper, I use the year before the construction of green fiscal policy demonstration cities, i.e. 2010, as the baseline, and adopt event analysis to conduct regression according to Model (5):

$$\begin{aligned} ln\ co2pergdp_{it} &= \beta_0 + \sum_{k=-5}^{4} \beta_k \times Treat_t \times I_k + \beta_2 target\_12 * Post + \gamma X_{it} \\ &+ \mu_i + \vartheta_t + \varepsilon_{it} \end{aligned} \quad (5)$$

$Treat_t$ represents a dummy variable, with a value of 1 when the city is in the control group at time t, and 0 otherwise. I_k is a dummy variable, with a value of 1 when the difference between year t and the year this city was selected as a demonstration city is k, and 0 otherwise. The rest of the settings remain the same as in Model (1). In this paper, the value of k is limited to between -5 and -1, and 0 to 4. Samples where k $\leqslant$ -5 are all classified as k = -5, and k = -1 is used as the baseline group. The other variables have the same meanings as in Model (1), and time trends are controlled for.

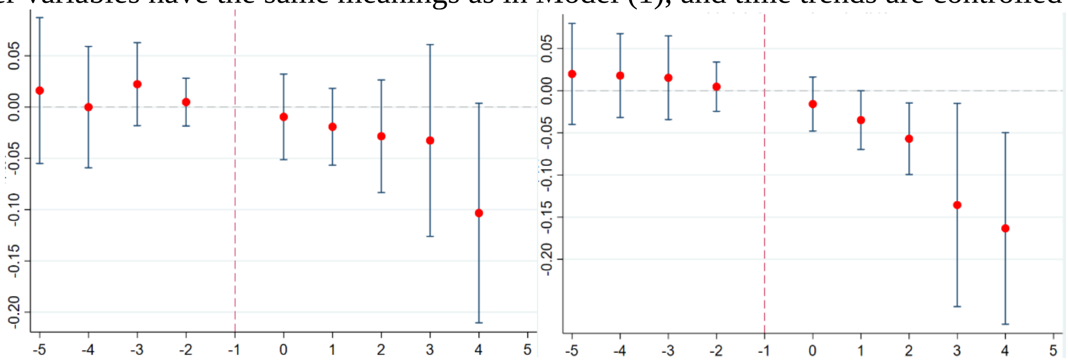

Figure 1: Parallel Trend Test (Left: Carbon Emission Intensity; Right: Per Capita Carbon Emissions)

According to Figure 1, in the five years before the construction of the demonstration cities, the policy coefficients for carbon emission intensity and per capita carbon emissions are not significant, and their regression coefficients are near zero. This indicates that prior to 2011, there were no significant differences in carbon emissions between the demonstration cities and non-demonstration cities, meeting the parallel trend assumption.

Furthermore, from the dynamic effects of the parallel trend test, both carbon emission intensity and per capita carbon emissions rapidly declined after the baseline year and changed from positive coefficients before the construction of demonstration cities to negative coefficients, indicating a significant carbon reduction effect of the "National Comprehensive Demonstration City of Energy Saving and Emission Reduction Fiscal Policy". The coefficients for each year after policy implementation show a significant downward trend, suggesting a lag in the effect of the demonstration city construction, which may be due to the learning effect of local governments during the construction process.

The construction of demonstration cities is a new, dynamic, and continually learning process, and the experience gained from the initial batch of demonstration city construction can provide useful guidance for subsequent batches of demonstration cities.

4.3 Robustness checks-Two-Stage DID

A series of recent literatures have proposed that when the time of individual treatment group receiving treatment is staggered, and the average treatment effect changes with the group and time, common differential estimation cannot identify a typical treatment effect and make reasonable measurements (Athey and Imbens, 2016; de Chaisemartin and D’Haultfoeuille, 2020; Sun and Abraham, 2021; Gardner 2021; Goodman-Bacon, 2021; Borusyak and Jaravel, 2021).

Gardner (2022) suggests that two-stage difference in differences may alleviate this problem. The specific operations are as follows: in the first stage, the pure control group is used for regression to identify the group effect and time effect and eliminate them; In the second phase, the average treatment effect was identified by comparing the difference in results between the treatment and control groups. In this paper, the standard error from clustering to city level is used when using two-stage differential method for regression.

This paper use two-stage DID to test the robustness of the carbon emission reduction effect of demonstration cities, and the regression results are shown in Table 5.

Table 5 Regression results of the two-stage DID

Two-stage DID	
carbon emission intensity	per capita carbon emissions
-.073***	-.072***
（.024）	（.025）

After two-stage DID analysis, the regression coefficient is still significantly negative, which indicates that the construction of demonstration cities still shows significant carbon emission reduction effect after taking the processing heterogeneity of DID at multiple time points into consideration.

5. Mechanism analysis

The empirical findings from the aforementioned staggered difference-in-differences (DID) model and a series of robustness tests provide evidence that the establishment of low-carbon fiscal policy demonstration cities effectively reduces both carbon emission intensity and per capita carbon dioxide emissions. How is this effect achieved?

The Guidance document clearly outlines the development direction of "industrial low-carbon." Research conducted by Chen Zhao et al. (2019) examines the decomposition of energy consumption in China's industrial sector, with a particular focus on high-energy-consuming industries. The findings demonstrate that energy efficiency plays a significant role in mitigating the growth of industrial energy consumption, whereas the impact of changes in industrial structure on energy consumption is relatively weak. Therefore, this paper argues that demonstration cities achieve carbon emission reduction by enhancing energy efficiency.

In this study, the dependent variable is substituted with energy efficiency, calculated as the logarithm of the current year's actual city GDP divided by the energy consumption in the same year. To obtain energy data, light data is utilized to decompose provincial-level energy consumption data into prefecture-level city-level data. GDP data is sourced from the China Urban Statistical Yearbook and adjusted to real GDP based on 2003. All other conditions remain consistent with Formula (1), and the regression results are presented in Table 6.

Table 6 Regression results of energy efficiency

VARIABLES	energy efficiency	energy efficiency
policy	0.237***	0.201***
	(0.080)	(0.066)
target12	0.020	0.025*
	(0.013)	(0.014)
Control variables	NO	YES
Observations	3,860	3,817
R-squared	0.798	0.828
City FE	YES	YES
Year FE	YES	YES

It can be seen that the regression coefficient of energy efficiency is significantly positive, indicating that the construction of demonstration cities has a significant effect on the improvement of energy efficiency. Moreover, after gradually adding control variables, the variation range of regression coefficient is relatively stable. Compared with non-demonstration cities, energy efficiency of demonstration cities increases by about 20%, which undoubtedly plays an important role in carbon emission reduction of cities and verifies hypothesis 2.

6. Conclusions

Low-carbon economic transformation is the inevitable choice of sustainable development, and actively implementing carbon emission reduction is an important starting point in the face of today's global environmental problems. Based on the quasi-natural experiment on the construction of the "National Comprehensive Demonstration City of Energy Saving and Emission Reduction Fiscal Policy" carried out during the 12th Five-Year Plan period, this paper discusses whether green fiscal policies can promote urban carbon emission reduction through staggered DID method, and discusses the effect of this policy on the synergistic effect of carbon reduction and pollution reduction and the promotion of local economic development. The research conclusions of this paper include the following four points: (1) The construction of comprehensive demonstration cities promotes the carbon emission reduction of demonstration cities, both carbon intensity and per capita carbon emissions have decreased significantly. (2) The construction of comprehensive demonstration cities has no significant impact on the carbon emissions of non-demonstration cities. (3) Comprehensive demonstration cities can reduce carbon emissions by improving energy efficiency. Moreover, the effectiveness of carbon reduction remains valid across the Two-Stage Difference-in-Differences (DID) analysis.

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