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Impact of Low-Carbon Policies on Carbon Emissions—Empirical Evidence from Low-Carbon City Pilot Policy

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Abstract: *Pilot policies for low-carbon cities have been in place since 2010, and their effectiveness remains to be seen. Therefore, this paper uses progressive difference-in-difference the urban panel data from 2007 to 2019 as a "Quasi-natural experiment" to evaluate the impact of low-carbon pilot policies on carbon emissions. The results show that low-carbon pilot policies can significantly reduce carbon emissions, and the robustness test is used to ensure the credibility of the results. And according to previous literature, low-carbon pilot policies generally reduce carbon emissions by improving energy efficiency, promoting industrial upgrading and technological innovation. This paper can provide some enlightenment for the study of low-carbon pilot effect.*

Keywords: *low-carbon pilot; carbon emissions; difference in difference*

1. Introduction

Global warming is causing great damage to the natural ecological environment. Carbon dioxide emissions due to human activities are the main cause of global warming from the mid-twentieth century to the present. As a major country in the world, China needs to take a number of measures to transform its economy to low carbon. In July 2010, the National Development and Reform Commission issued a pilot policy notice, identifying the first batch of pilot areas including five provinces including Shaanxi Province and Yunnan Province and eight cities including Baoding City and Xiamen City. In 2012, after the implementation of the first batch of pilots, the NDRC issued the first batch of pilots in November 2012 in order to strengthen the demonstration role. The second batch of policy pilot notices, the pilot areas are determined to be 29 provinces and cities including Hainan Province, Shijiazhuang City, Shanghai City, and Wuhan City. In 2017, the third batch of pilot areas was identified as 45 cities and counties, including Wuhan, Shenyang and Nanjing. Studies have pointed out that China's pilot policies in various batches have significant effects in reducing carbon emissions. Moreover, most of China's low-carbon city pilot policies are original policy content. To sum up, China's low-carbon city pilot policy has distinctive characteristics, and it still has research value to understand the impact of the pilot policy on the effect of carbon emission reduction.

The content of this paper is arranged as follows: the second part is a literature review; The third part is study design; The fourth part is the analysis of empirical results, including parallel trend test, regression result, placebo test and robustness test; The final part is conclusions and policy implications.

2. Literature review

The research covered in this paper focuses on the evaluation of low-carbon pilot policies and the impact of China's low-carbon transition on carbon emissions. In order to summarize the research progress in these two aspects in recent years, the articles related to this paper are described as follows. Since the implementation of low-carbon pilots in 2010, scholars have mainly carried out economic effects, environmental effects, and social effects when studying the utility of low-carbon pilots, and the content has focused more on economic effects. For example, the results showed that the policy provides impetus for enterprises to carry out green technology innovation, and the promotion effect on high-carbon industries and non-state-owned enterprises is more prominent [1]. This paper used data from 2007 to 2019 and used the gradual double difference model, and low-carbon pilot policies will promote employment[2].In recent years, more and more literature has paid attention to the role of low-carbon

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transformation on carbon emissions, and it is generally believed that the implementation of low-carbon policies effectively reduces carbon emissions. Studies show that improving energy efficiency and upgrading industrial structure, and green technology innovation[3] reduce urban carbon emission intensity [4], reduce air pollution[5], and low-carbon pilots can also achieve the effect of equitable carbon emission reduction[6]. By comparing carbon emissions under the general equilibrium model with the carbon neutrality target, carbon emissions under the carbon neutrality target can be reduced with limited economic impact[7].In addition, this paper proposed carbon subsidies to offset the costs of green technology innovation[8].

It can be seen that scholars have conducted more adequate research on low-carbon pilot policies, but there are the following shortcomings: more research focuses on the economic effects of low-carbon pilots, while less research on the social effects brought by them. To this end, this paper studies the impact of low-carbon pilot policies on carbon emissions and analyzes the social benefits brought by them.

3. Study design

The National Development and Reform Commission has launched three batches of low-carbon city pilots since 2010. The first, second and third batches of pilots were launched on July 19, 2010, November 26, 2012 and January 7, 2017 respectively.

3.1. Model building

The implementation of China's low-carbon pilot policy will produce two differences, for the same city, carbon emissions before and after the implementation of the policy will be different; For the same point in time, the carbon emissions of pilot cities and non-pilot cities will also be different, and based on these two differences, the double difference method is used for regression analysis[9].

The model is designed as follows:

$$co2ct=\alpha 1+\beta 1Treatc\times Postt+\lambda 1Zct+\mu c+\eta t+\varepsilon ct \quad (1)$$

Among them, CO2ct as the explanatory variable refers to the carbon emissions of city C in T year; β1is a double difference estimator, which measures the impact of low-carbon pilots on carbon emissions, which is the main research coefficient in this paper. Treatc is a dummy variable that indicates whether city C is a low-carbon city pilot, and if city C is a pilot city, the value is 1, and vice versa is 0; Postt is the variable that represents the time, 1 if the pilot is carried out in year t, and 0 vice versa; μc represents the urban fixed effect, and ηt represents the year fixed effect; εct is a random perturbation term; Zct represents a series of control variables affecting urban carbon emissions in T year.

3.2. Data selection and processing

This paper takes 2007-2019 as the study period, and the sample is 121 pilot cities and 166 non-pilot cities in China. CO2 is expressed as the logarithm of a city's carbon emissions, which comes from the China Carbon Emissions Database, and the rest of the data comes from the China Cities Statistical Yearbook. Due to the lag in the implementation effect of the pilot policy, in order to facilitate the research, In this paper, the three batches of pilot projects are set in 2010, 2013, and 2017.At the same time, drawing on Song Hong et al. (2019), if a province is a low-carbon pilot city, all cities in the province are regarded as low-carbon pilot cities, and if a city has multiple policy implementation times, it is determined according to the earliest time, shown in Table 1and 2:

Table 1: Controls variable selection.

Variable name	Variable meaning	Calculation method
Pgdp	Level of economic development	The logarithm of GDP per capital
Peo	Population size	The logarithm of the total population at the end of the year in the city
ind	Level of industrialization	The proportion of the added value of the secondary industry in the regional GDP
urb	Level of urbanization	The proportion of urban population in the total population
es	Energy structure	The ratio of coal consumption to total energy consumption

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Table 2: Descriptive statistics for variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
co2	3705	12.266	.768	9.948	14.652
Treat*Post	3705	.259	.438	0	1
pgdp	3705	10.477	.688	4.595	13.056
peo	3705	5.874	.695	2.898	8.136
ind	3705	48.381	12.192	9.74	90.97
urb	3705	52.938	10.071	28.24	89.6
es	3705	.445	.132	.01	.72

4. Analysis of empirical results

4.1. Benchmark regression results

As can be seen from Table 3, the impact coefficientβ1 of low-carbon pilot policies on urban carbon emissions is -0.0295, and is significant at the level of 0.1. The results showed that after considering the five control variables, the implementation of the policy could significantly reduce the carbon emissions of the pilot cities, and the carbon emissions of the pilot cities were reduced by about 2 on average compared with the non-pilot cities 95%.

Table 3: Benchmark regression results.

	(1)
VARIABLES	co2
Treat*Post	-0.0295*
Controls variable	(0.0153) yes
Constant	9.464***
	(0.592)
Observations	3,705
R-squared	0.987

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2. Parallel trend test

Passing the parallel trend test is the premise of using the double difference method. Therefore, this paper uses the event study method to test the parallel trend, which can be expressed as:

$$coct=\alpha 2+\sum_{t=-4}^{7} \beta t \times Dct+\lambda 1Zct+\mu c+\eta t+\varepsilon ct \quad (2)$$

Among them, βt is the key focus factor in this formula, reflecting the difference in carbon emissions between low-carbon pilot cities and non-pilot cities in the tt year of policy implementation. Dct is a set of dummy variables, with a value of 1 if city C implements a pilot policy in year t, or 0 if it is not implemented. The remaining variable symbols have the same meaning as the symbols in Equation (1).As can be seen from Figure 1, there is no significant difference between the pilot and non-pilot cities before the implementation of the low-carbon policy, so the selected sample passed the parallel trend test.

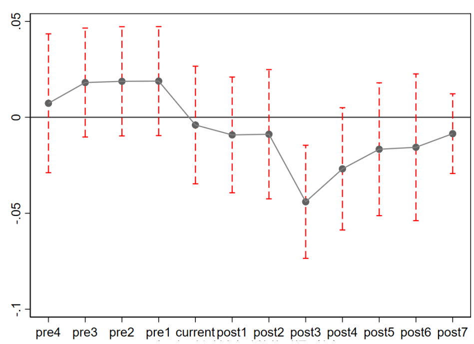

Figure 1: Parallel trend test result.

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4.3. Placebo test

First, 121 cities were randomly selected in the sample cities and used as a dummy treatment group, while the remaining cities were used as a sham control group for placebo testing. It can be seen from Figure 2 that the regression coefficient falls around 0 and the pattern is normally distributed, and most of the regression results are not significant. Therefore, inaccurate baseline regression results due to not observable values can be ruled out.

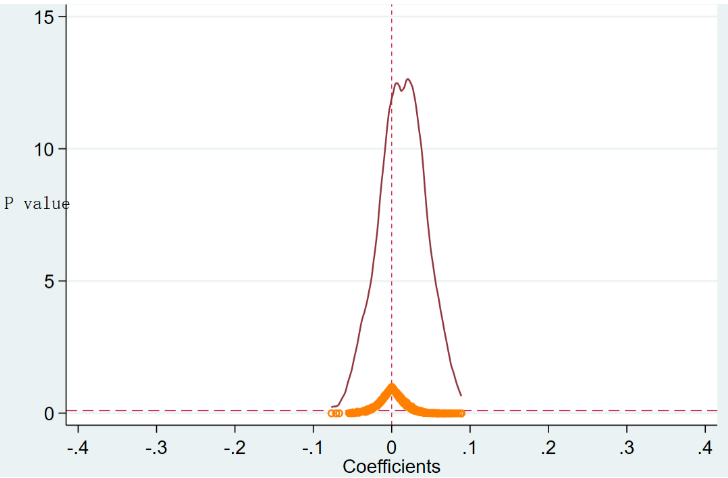

Figure 2: Placebo test result.

4.4. Robustness test

After truncating 1% and 5% of the co2 samples of the explanatory variables, the regression results are listed in Table 4, (1) and (2), and the results show that the coefficient regression values of Treat×Post are significant at the level of 0.05 and 0.1, respectively, after removing the extreme values. Column (3) is the result after using the propensity matching score, indicating significant at the level of 0.1, which is similar to the benchmark regression result.

Table 4: Robustness test results.

	(1)	(2)	(3)
VARIABLES	co2	co2	co2
Treat*Post	-0.0321**	-0.0427***	-0.0887***
	(0.0144)	(0.0140)	(0.0185)
Controls variable	yes	yes	yes
Observations	3,705	3,705	1,918
R-squared	0.987	0.985	0.733

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. Conclusions and policy implications

Through the above analysis, the results show that the pilot policy of low-carbon cities can reduce carbon emissions. Based on the conclusion, this paper puts forward the following policy implication. Summarize the experience of low-carbon city pilots and promote the successful experience of low-carbon urban transformation to other parts of China. The government departments of pilot cities can summarize the practical experience, promote low-carbon reform, develop green economy, drive cities to carry out high-quality development, and contribute to achieving carbon peak and carbon neutrality.

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