The Impact of China's Low-Carbon City Pilot Policy on Reduction of Carbon Emissions

Estimation and Analysis Based on Panel Data of 275 Cities

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ABSTRACT

Are rigid constraints are necessary to meet carbon reduction targets? The study used data from 275 prefecture-level cities in China from 2006 to 2016 to establish a two-way fixed-effect DID model that passed the parallel trend test, heterogeneity analysis, and robustness test to investigate the impact of a typical weak incentive policy, China's low-carbon city pilot policies implemented in 2010 and 2012. This method assesses the pilot policy's effectiveness as well as any interfering elements. First, a national low-carbon policy can dramatically reduce carbon emissions, according to the study. Second, the pilot batch and pilot scope result in heterogeneity in implementation effect. Last, by adding the quadratic term into the model, Gdp and second industrial output indicate an "inverted U-shaped" relationship with carbon emission, which verified the "Environmental Kuznets Curve(EKC)".

Keywords: *Low-Carbon City Pilot Policy, Carbon Emission, Emission Peak, DID.*

1. INTRODUCTION

An executive meeting of the Chinese State Council in November 2009 established a target for measures to reduce greenhouse gas emissions by 40%-45% by 2020, compared to 2005[1]. China's carbon intensity had decreased by about 48.1 percent since 2005[2], and the share of non-fossil energy in primary energy consumption had increased to 15.3 percent[3], meeting the Intended Nationally Determined Contributions (INDCs) made at the Copenhagen Climate Change Conference ahead of schedule.

Looking back over the last decade of emission reduction progress, the introduction of a low-carbon pilot strategy is without a doubt a significant milestone. The Central Economic Work Conference in December 2009 issued a positive signal to "launch low carbon economy pilot and control greenhouse gas emissions"[4], as part of the 2020 action target to control greenhouse gas emissions, and the National Development and Reform Commission began issuing top-down low-carbon development policies. Three batches of low-carbon provinces, regions, and cities were launched in July 2010, November 2012, and January 2017, including 8 provinces and 61 cities[5]. In this research, only the first two batches of low carbon pilot cities are examined because the third batch was only implemented for two years (2017-2019).

In terms of distribution characteristics, the first batch was geographically balanced, covering developed eastern coastal regions, central regions, late-developing western regions and old industrial bases in the northeast, each with its representative level of economic development and energy consumption; the second batch was selected to spread low-carbon pilots across the country, exploring the paths of effective greenhouse gas control measures among different regions.

However, in terms of policy strength, the low-carbon city pilot policy is a typical weak incentive policy that does not set specific emission reduction targets, but rather provides support for emission reduction in terms of funding and project priority[6]. The study may provide an answer to the question of whether rigid constraints are necessary to meet carbon reduction targets.

There has been much academic research on low-carbon pilot policies. Deng Rongrong[7] et al. (2017) studied the eight first low-carbon pilot cities in China through the difference in difference (DID) method and found that the policy impact increased with the number of years after implementation; Zhou Di[8] et al. (2019) used the propensity score matching (PSM) method for sample matching; Song Hong[9] et al. (2019) used the DID method followed by an examination of the conduction mechanism of the policy’s impact on air quality.

However, the academia’s current research on low-carbon pilot policies is mainly based on state-level data or province-level data (Dai Rong[10] et al., 2017; Dong Mei[11] et al., 2020), and the conclusions drawn are too macroscopic. The few studies based on prefecture-level analysis (e.g. Feng Tong[12], 2016) only cover a narrow and uneven distribution of urban agglomerations.

As a result, the study treats China's national low-carbon city pilot policy as a quasi-natural experiment, examining its impact on carbon emissions reduction using DID models. The following are the paper's research contributions:

First, the study extends the scope of the research to the prefecture level and covers the first and second batches of pilot cities. However, the third batch of pilot cities is not included in the scope of this study due to the relatively short period since the policy was implemented.

Second, the research validated the Environmental Kuznets Curve(EKC), which was proposed by American economist Simon Smith Kuznets in 1955[13] and later applied to the field of environmental economics. EKC illustrates that in the initial stage of economic development, economic growth leads to an increase in environmental pollution, but when per capita income exceeds a certain level, the opposite trend is obtained, i.e., economic growth causes environmental improvement when per capita income is at a higher level[14].

Third, to provide more focused conclusions on the effects of low carbon pilot policies, the study undertakes a heterogeneity analysis, taking into account the influence of different pilot batches and pilot levels.

2. EMPIRICAL MODEL SETTING AND VARIABLE DESCRIPTION

2.1. Model Settings

China identified low-carbon pilot regions in six provinces and 36 cities in the first two batches. Pilot policies are analyzed as a quasi-natural experiment in this study, with pilot cities serving as the experimental subjects and non-pilot cities serving as the control group.

Establish the model as follows:

$$E_{it} = \beta_0 + \beta_1 test_{it} + \beta_j control_{it} + \gamma_t + \mu_i + \varepsilon_{it} \quad (1)$$

Establish the log model as follows:

$$LnE_{it} = \beta_0 + \beta_1 test_{it} + \beta_j Lncontrol_{it} + \gamma_t + \mu_i + \varepsilon_{it} \quad (2)$$

The subscripts i and t stand for city and year, respectively. The carbon output per capita is denoted by the E_{it}. $test_{it}$ is a dummy variable that represents the timing of the city pilot policies' implementation. Cities' pilot policies and later years will be set to one, while the rest will be put to zero. Gdp per capita(*Gdp*), the proportion of secondary industry output(*Sec*), foreign direct investment(*Fdi*), number of universities(*Uni*), and fiscal expenditure(*Fis*) are all control variables, represented by $control_{it}$; γ_t and μ_i signify city fixed effect and time fixed effect respectively. The coefficient in question is β_1, which indicates the influence of low-carbon pilot programs on carbon emissions in the aforementioned calculation.

2.2. Variable Description

The sample covers panel data for 275 cities in China from 2006 to 2016, encompassing the implementation years of the first and second batches of low-carbon pilot policies, due to a substantial amount of missing data for several cities. The dependent variable E_{it} is calculated by the following equation:

$$E_{it} = FC_i \times CAL_i \times CCi_i \times CO_i \quad (3)$$

The subscript i represents energy sources, based on data from the “China Energy Statistical Yearbook”, including eight energy sources: coal, coke, crude oil, fuel oil, gasoline, paraffin, diesel and natural gas. The energy composition and total energy consumption(*FC*) are from the “China Energy Statistics Yearbook” of each year; the energy calorific value coefficient(*CAL*) is from the “China Energy Statistics Yearbook(2008)”; the carbon content of various fuels(*CCI*) and carbon oxidation rate(*CO*) are from the energy section of the IPCC report. All the above parameters are exogenous.

The data of control variables are mainly obtained from the “China Urban Statistical Yearbook (2007-2017)” for independent variables such as Gdp per capita, the share of secondary industry output, foreign direct investment number of universities, fiscal expenditure and population.

3. EMPIRICAL MODEL ANALYSIS

3.1. Parallel Trend Test

The double difference model is valid under the assumption of convergence, i.e. if no low carbon pilot policy is implemented, the trend of carbon emission changes in low carbon cities and other cities should be parallel. The research uses event stud to test the parallel trend. According to Figure 1, before the implementation of the policy, the β coefficient is relatively flat, while from the beginning of the policy implementation, the β coefficient starts to decrease significantly, indicating the effectiveness of the policy.

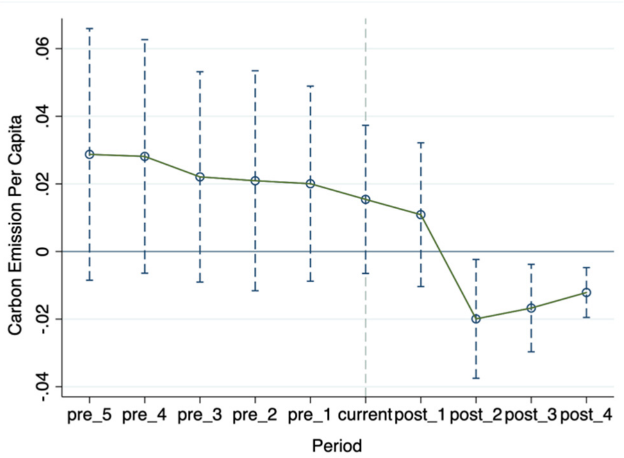

Figure 1 Event study result

3.2. Basic Regression Model Estimation

Table 1 shows the basic regression results. The study uses models (1) and (2) to evaluate the impact of the low-carbon city pilot policy on emission reductions without controlling for factors. Then control variables are added in models (3) and (4), which are estimated using two-way fixed effects. The results demonstrate that the pilot policy is significantly positive at 1%, indicating that the pilot policy has the potential to dramatically cut city carbon emissions.

Table 1 Basic regression results

	(1)	(2)	(3)	(4)
	E	Ln E	E	Ln E
Test	-0.601**	-0.036**	-1.001***	-0.039***
	(-2.08)	(-2.42)	(-3.28)	(-2.93)
Gdp			1.044***	
			(6.22)	
dGdp			-0.016***	
			(-5.38)	
Sec			0.351*	0.060
			(1.80)	(0.94)
dSec			-0.004*	
			(-1.71)	
LnGdp				0.191***
				(3.63)
FE	YES	YES	YES	YES

Note: The coefficients of ***, **, and * in the table show that the inspection level was passed at 1%, 5%, and 10%, respectively. Due to a lack of space, further variables and R parameters were excluded.

In the linear model, the quadratic coefficients of total Gdp are negative and the primary coefficients are positive, both significant at the 1% level. The result shows that the level of national income is positively correlated with the level of carbon emissions at first and that when Gdp grows to a certain level, carbon emissions instead decline as the level of national income increases. As a result, there is an overall inverted U-shape in the link between carbon emissions and economic progress, which is compatible with the EKC theory. Similarly, the results indicate that carbon emissions rise and then fall as the share of the secondary sector rises, which also matches the inverted U-shape relationship.

According to calculations of the inflection point of the Gdp-emission curve, over 90% of cities have not yet crossed it, indicating that we still have a long way to go before the emissions peak. But considering the inflection point of Share of second industry output-emission, the situation is much better.

3.3. Heterogeneity Analysis

The outcome of heterogeneity analysis is shown in Table 2's regression results. The impact of the first batch of low-carbon pilot cities is much bigger than that of the second batch of low-carbon pilot cities, according to the regression results of models (5) and (6). This could be due to the fact that the first batch of low carbon pilot cities has been in place for longer and has a broader impact; second, it could be due to the fact that the second batch has a larger number of low carbon pilot cities, so the policy impact received by a single pilot city is weaker and less targeted.

According to models (7) and (8), the pilot cities have a stronger effect than pilot provinces on carbon emission reduction. Probably due to the fact that cities have smaller administrative boundaries and are easier to manage and control, while provincial low carbon pilots have various problems such as conflict of interest within the province, which affects the efficiency of policy implementation.

Table 2 Heterogeneity analysis results

	(1) 1st batch	(2) 2nd batch	(3) Province	(4) City
Test1	-0.040*** (-2.72)			
Test2		-0.048* (-1.90)		
TestP			-0.035** (-2.24)	
TestC				-0.049** (-2.52)
Controls				0.191***
FE	YES	YES	YES	YES

3.4. Robustness Test

Table 3 displays the findings of the robustness test performed to confirm that the emission reduction effect found at the end of this study is due to the low carbon pilot policy implementation rather than other factors.

First, the regression includes a relevant policy. The National Development and Reform Commission said in January 2012 that Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen were among the first seven provinces and cities to implement a carbon emissions trading pilot strategy. This policy, which is identical to the low carbon pilot program in terms of length and purpose, could be used as a good confounder for the target policy's robustness test.

By including relevant policy, the carbon emission trading policy into the regression model, the significance of pilot policy decreases slightly in model (9), but remains significant at 5% level, while carbon emission trading policy is also proved to be significant, contributing to the reduction of carbon emission.

Table 3 Robustness test results

	(9) Add policy	(10) Pre_1	(11) Pre_2
test	-0.033** (-2.58)		
Test_policy	-0.108** (-2.50)		

Test_pre1		-0.023** (-2.25)	
Test_pre2			-0.010** (-0.67)
Controls	YES	YES	YES
FE	YES	YES	YES

Next, testing by bringing forward the implementation of the policy by one or two phases. According to the results in table 3, when the policy is advanced by one period, the policy effect is significant at the 5% level, which is weaker than the effect when the policy is not advanced; while when the policy is advanced by two periods, the policy effect is not significant. Therefore, the placebo test is passed.

The reason why the coefficient remains significant when the policy is advanced by one period could be: first, the policy was preceded by other relevant policies or guidance documents, which created expectations of emission reduction in the market, and therefore many regions had already reacted before the policy was implemented; secondly, the first batch of low-carbon pilot cities may have already pre-empted the corresponding governance and regulation of the city's emissions before the declaration, resulting in emission reduction actions already existing in the first period before the policy took place.

4. CONCLUSION

This study came to the following conclusions after examining the impact of low-carbon pilot initiatives on urban carbon emissions.

First, low-carbon pilot strategies reduce carbon emissions significantly. Even after other policy shocks were added, the considerable effect remained.

Secondly, the implementation effects varied across batches and city levels: the first batch of pilots was more effective than the second batch, probably due to the longer and more targeted implementation of the policies in the first batch of pilots. At the same time, the pilot cities had better results than the pilot provinces, again probably because the policy was more targeted and operational for the cities.

Third, the EKC exists and there is a long way to go to break the inflection point. Carbon emissions intensity falls with Gdp growth or when the share of secondary industries reaches a particular level, forming a strong "inverted U-shaped" curve between carbon emissions intensity and economic growth. This curve has been verified in this study. However, the above analysis shows that most cities are located in the lower-left part of the curve and are still far from the inflection point of Gdp per capita.

5. PROSPECT

Although three batches of low-carbon pilot policies have been implemented, with the introduction of the “carbon peaking and carbon neutrality goals”, China still needs to face the double constraint of emission reduction targets and economic growth targets, which will be a great challenge for policy formulation. This paper validates the effectiveness of the weak incentive policy represented by the pilot cities, but there is still a need for refinement in terms of policy implementation. Several ideas are provided as follows.

First, regional differences are factors that must be taken into account for low-carbon emission reduction. For cities that have already experienced long-term intensive development, the key breakthrough direction for future emission reduction lies in optimizing the energy structure and low-carbon technological innovation; while for cities that are highly energy-dependent, heavy industry-intensive and sloppy development, accelerating the elimination of backward production capacity and changing the resource-intensive mode of economic growth are the top priorities.

Second, according to the Porter hypothesis (Porter, 1991), appropriate and strict environmental rules might lead to more inventive activities, hence increasing enterprise productivity and competitiveness. Low-carbon city policies should prioritize both emissions reduction and development, utilizing a variety of market-based tools such as carbon emissions trading, contract energy management, and other market-based tools, as well as the development of green finance, to achieve a 'win-win' for both environmental and economic goals.

Finally, Although the voluntary policy tool of weak incentives gives cities ample room for autonomous development, it also suffers from a lack of management and failed declarations. Future emissions reduction policies should try to overcome the inherent weaknesses of weak incentives, improve policy implementation, adopt a fair and open approach to give cities that are able and willing to declare sufficient lead time and specific assessment indicators and make the results of each indicator transparent and public.

AUTHORS' CONTRIBUTIONS

Yichen Shi: Conceptualization, Methodology, Formal analysis, Data Curation, Writing, Visualization.

Taizhe Huang: Conceptualization, Methodology, Data Curation, Writing, Editing.

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