ISSN 2616-5872 Vol.6, Issue 5: 1-6, DOI: 10.25236/AJEE.2024.060501

Analysis of the Effectiveness of New Energy City Demonstration Policies in Guangxi--Based on Carbon Double Difference Modeling

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Abstract: *Carbon emissions refer to the emission of carbon-based gases such as carbon dioxide in the process of energy consumption. The new energy demonstration policy is an important policy in China's energy transition process. There is no relevant literature to scientifically assess the impact of the new energy demonstration policy on carbon emissions in Guangxi, and there is a lack of in-depth elaboration on the mechanism of the new energy demonstration cities. Therefore, this paper uses panel data of 14 cities above prefecture level in Guangxi from 2003 to 2022 to identify the policy effects of Guangxi's new energy demonstration city policy on carbon emissions by using a double difference model with the new energy demonstration city policy as a quasi-natural experiment, and tests the robustness of the new energy demonstration policy by using counterfactuals and excluding the interference of other policies to fill the gap in the effects of Guangxi's new energy demonstration city policy.*

Keywords: *Total Carbon Emission, Per Capita Carbon Emission, New Energy Demonstration Policy, Double-Difference Modeling*

1. Introduction

There are many academic studies on new energy demonstration policies. Researchers (Jing Guowen and Wang Da 2024)[1] analyzed the panel data and found that technology and environmental regulation are important factors influencing new energy demonstration cities to achieve carbon emission reduction, and researchers (Lin Yumiao, Cheng Qiuwang, and Xu Anxin 2024)[2] . After the usual trend test, it is similarly concluded that new energy demonstration cities play a significant positive moderating role between policies and carbon emissions. This paper combines the methods of previous scholars to further test the robustness of the double-difference model in various aspects, which further explains the role of new energy demonstration policies on carbon emissions.

2. Modeling and Solving

2.1. Modeling

In this paper, the new energy demonstration city policy is used as a quasi-natural experiment to identify the carbon emission intensity of Guangxi's policy through the double difference method (DID). According to the double-difference experimental method, the following dummy variables are constructed: ① experimental group, control group and policy dummy variables: the experimental group is new energy demonstration cities, quantitatively 1; the control group is non-demonstration cities, quantitatively 0. ② time dummy variables, the year when the policy is implemented: after 2014 is defined as 1, and before 2014 is defined as 0. This paper processed the sample data, and the final sample data include Nanning City, Liuzhou City, Guilin City, Wuzhou City, Beihai City, Fangchenggang City, Qinzhou City, Guigang City, Yulin City, Baise City, Hezhou City, Hechi City, Laibin City, and Chongzuo City in Guangxi Province, of which there are 3 new energy demonstration cities and 11 non-new energy demonstration cities.

The model is set up as follows:

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$$tce_{cy} = \alpha + \beta DID_{cy} + \gamma control_{cy} + \lambda_c + \theta_y + \delta_{cy} \quad (1)$$

$$pce_{cy} = \alpha + \beta DID_{cy} + \gamma control_{cy} + \lambda_c + \theta_y + \delta_{cy} \quad (2)$$

where c denotes city, y denotes year, tce denotes total carbon emissions, pce denotes per capita carbon emissions, control is a series of control variables, λc denotes city fixed effects, and δcy denotes a random error term.$DID_{cy} = city_y \times year_c$,city denotes the policy dummy variable, with 1 for demonstration-level cities and 0 for non-pilot-level cities; year is the time dummy variable, with$year \geq 2014$ as 1 and$year < 2014$ for 0.

2.2. Selection of variables

2.2.1. Explained Variables

①Total carbon emission is an important indicator of energy transition. This paper is based on (Wu Jianxin and Guo, Zhiyong 2016)[3] , (Liu Xiping 2017)[4] , (Zhang Hua 2020)[5] et al. The sources of urban carbon emissions are divided into two categories: direct carbon emissions and indirect carbon emissions. Direct carbon emissions include oil, coal, natural gas, etc., and indirect carbon emission sources include carbon emissions from energy consumption such as electricity. In this paper, the carbon emission factor of standard coal recommended by the Energy Research Institute of the National Development and Reform Commission (NDRC) and the total energy consumption of the city are used to calculate the carbon emission from direct energy sources; the carbon emission from indirect energy sources is calculated by using the emission factor of the baseline of the Southern China Regional Power Grid of the Emission Reduction Project in 2021 and the consumption of electricity of the whole society in the city. The total carbon emissions in this paper is equal to the indirect carbon emissions plus direct carbon emissions. Per capita carbon emission is divided by the total household population, which is an important reference index for energy transition.

2.2.2. Core Variables

In this paper, we refer to (Li Yuxin 2023)[6] 's study to introduce the core variable: new energy demonstration city pilot policy (did). The article uses a double difference term to measure the core explanatory variable, which is 1 if the city is selected as a new energy demonstration city and the year is in 2014 and later, and 0 otherwise.

2.2.3. Control Variable

This paper refers to (Zhang Hua 2020)[5] , (Li Yuxin 2023)[6] The following control variables are introduced: ① the level of economic development, expressed as the logarithm of the per capita gross regional development value; ② the level of fixed asset investment, expressed as the logarithm of the share of regional fixed asset investment in the nominal GDP of the region; ③ the degree of government intervention, expressed as the logarithm of the share of the total regional fiscal expenditure in the nominal GDP of the region; ④ the resident population, expressed as the logarithm of the resident population of the region; ⑤ the share of the secondary industry, expressed as the share of the value added of the secondary industry of the region in the nominal GDP of the region. ⑥ the efficiency of resource allocation, with the input factor as the number of employees, and the output as the real GDP; ⑦ the government's scientific and technological support, expressed as the proportion of the government's total scientific and technological expenditures to the regional total expenditure; ⑧ The city scale: the city population density is logarithmically expressed.

2.2.4. Data Description

Balanced panel data of 14 prefecture-level and above cities in Guangxi from 2003 to 2022 are selected as the study sample to assess the impact of new energy demonstration city policies on total carbon emissions. The data related to the study sample were obtained from the China Urban Statistical Yearbook, the CECN statistical database, the EPS database, and the statistical yearbooks and statistical bulletins of various cities. The descriptive statistics of variables are shown in Table 1.

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Table 1: Descriptive statistics of variables

variable name	variable symbol	sample size	average value	statistic standard deviation	minimum value	upper quartile	minimum value
Pilot policy	DID	280	0.096	0.296	0.000	0.000	1.000
Carbon emissions per capita	pce	280	1.001	0.604	0.199	0.881	3.764
Total carbon emissions	tce	280	5.988	0.711	4.058	5.989	7.773
Level of economic development	ve	280	10.004	0.773	7.966	10.131	11.424
fixed-asset investment	inv	215	-1.128	0.753	-3.076	-1.087	0.179
Level of government intervention	gv	280	-1.787	0.412	-3.390	-1.794	-0.719
Total resident population	rpp	280	5.724	0.536	4.368	5.839	6.790
Share of secondary industry	sit	279	-0.941	0.330	-3.230	-0.903	-0.415
Resource allocation efficiency	RE	252	1.515	0.769	0.022	1.564	2.933
Government scientific and technological support	MT	280	0.004	0.005	0.000	0.002	0.030
city scale	scale	280	7.449	0.688	5.557	7.616	8.813
t		280	12.500	5.777	3.000	12.500	22.000

Data source: Collated from this article

3. Analysis and Testing of Results

3.1. Benchmark Regression

In this paper, the regression results are presented by adding explanatory variables, control variables step by step while controlling for differences in time and city when using double difference method for regression. The regression results after adding explanatory variables and control variables sequentially are expressed.

From the regression effect of the total carbon emission column (2) in Table 1, it can be seen that the regression coefficient of the dummy variable (DID) of the pilot policy is -0.068, and it is significant at the 10% level, indicating that the implementation of the new energy demonstration city policy effectively reduces the total carbon emission of the pilot city, compared with the non-pilot city by 6.8%. The new energy demonstration city policy is designed to promote the revolution of energy production and consumption, promote the construction of ecological civilization, and give full play to the role of renewable energy in adjusting the energy structure and protecting the environment. Because the new energy demonstration city policy started in 2014, the estimated coefficients of the baseline model deal with the average treatment effect of eight years, which means that the new energy demonstration city policy has contributed to a decrease in total carbon emissions in the pilot cities by 85 kpc per year (0.068/8); as can be seen from the regression effect of the per capita carbon emissions column (2) in Table 1, the regression coefficient of the dummy variable for the pilot policy (DID) is 0.275 and is significant at the 10% level, indicating that the implementation of the new energy demonstration city policy effectively reduces the total carbon emissions of the demonstration city, which rises by 27.5% compared with the non-demonstration city. Because the new energy model city policy started in 2014, the estimated coefficients of the baseline model deal with the average treatment effect over eight years,

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which means that the new energy model city policy contributed to a decrease in total carbon emissions in the model city by 3.48 percentage points per year (0.275/8).

Table 2: Benchmark regression results

variant	Total carbon emissions		Carbon emissions per capita	
	(1)	(2)	(1)	(2)
DID	0.733***	-0.068*	-0.548***	0.130*
	(15.34)	(-2.01)	(-8.78)	(1.87)
ve		0.529***		-0.925***
		(8.45)		(-5.86)
inv		0.058**		-0.063
		(2.31)		(-1.55)
gv		-0.441***		0.275
		(-7.28)		(1.74)
rpp		0.243		0.593
		(1.35)		(1.77)
sit		0.068***		-0.13**
		(3.72)		(-3.67)
RE		0.002		0.035**
		(0.18)		(2.43)
MT		-1.578		28.447***
		(-1.14)		(3.86)
scale		-0.0352*		-0.022
		(-2.13)		(-0.31)
t		0.034***		0.023
		(3.39)		(1.41)
_cons	5.917***	-1.520	1.054***	6.883**
	(1158.71)	(-1.23)	(174.94)	(2.39)
urban fixed effect	YES	YES	YES	YES
time fixed effect	YES	YES	YES	YES
N	280	212	280	212
R2	0.110	0.977	0.068	0.867

Data source: Organized by this article. Note: *p<0.1, **p<0.05, ***p<0.01; values in parentheses are t-values. Total carbon emissions (tce) and per capita carbon emissions (pce) are the explanatory variables.

Regarding the estimation results of the control variables, this paper interprets them in column (2) of Table 2 for total carbon emissions and per capita carbon emissions. The estimated coefficient of the proportion of secondary industry (sit) is significantly positive to the total carbon emissions, indicating that the increase of the proportion of secondary industry increases the total carbon emissions, and thus the optimization of industrial structure is conducive to the reduction of carbon emissions. The estimated coefficient of the degree of government intervention (gv) is significantly negative on total carbon emissions, indicating that fiscal decentralization has a greater impact on total carbon emissions. Increasing the fiscal revenue of local governments is conducive to reducing total carbon emissions. Therefore, the experimental results are consistent with hypothesis 3. The estimated coefficient of the proportion of secondary industry (sit) is significantly negative to per capita carbon emission, indicating that the optimization of industrial structure can effectively inhibit per capita carbon emission.

3.2. Parallel Trend Test

This article is based on (Harris 2011)[7] et al. The treatment and control groups before the policy implementation should have the same trend of change or no significant systematic differences, so that the parallel trend is established for the double difference model to get accurate causal identification. Figure 1 presents the trend of total carbon emissions in demonstration and non-demonstration cities, the treatment group (demonstration cities) and the control group (non-demonstration cities) have the same trend of change before the policy implementation, and the trend of change after the policy implementation is obvious. Figure 2 presents the trend of per capita carbon emissions change in demonstration and non-demonstration cities, with the treatment group (demonstration cities) and control group (non-demonstration cities) showing the same trend before the policy implementation, and the trend after the

ISSN 2616-5872 Vol.6, Issue 5: 1-6, DOI: 10.25236/AJEE.2024.060501

policy implementation is obvious.

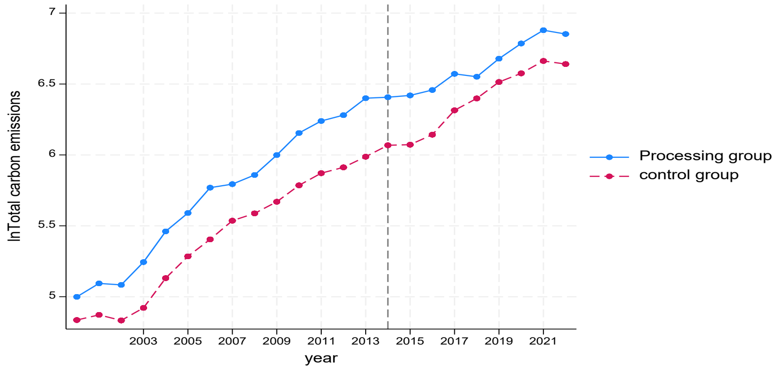

Figure 1: Trends in total carbon emissions in demonstration and non-demonstration cities

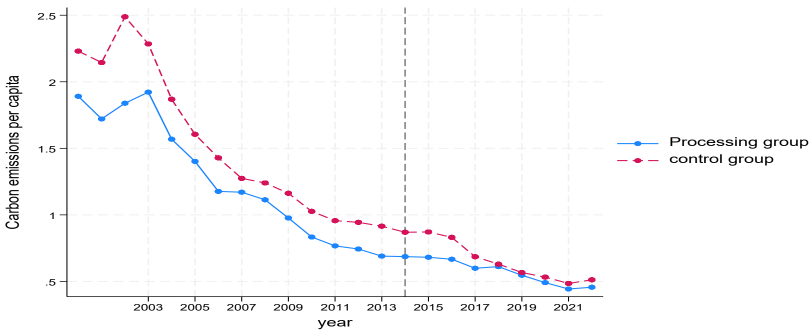

Figure 2: Trends in per capita carbon emissions in demonstration and non-demonstration cities

4. Conclusion

Based on the above data results, the following conclusions can be drawn: ① the implementation of the new energy demonstration city policy significantly reduces the total carbon emissions of the new energy demonstration city, with a reduction effect of 6.8% ∽ 7.4%; at the same time, it significantly improves the per capita carbon emissions of the new energy demonstration city, with an improvement effect of 13% ∽ 14%, which also proves the effectiveness of the new energy demonstration city policy; ② the new energy demonstration cities inhibit total carbon emissions through the industrial structure and local economic development level, the degree of intervention by local governments, etc. ③ Under the new energy demonstration city policy, the total emissions of Guangxi Zhuang Autonomous Region decreased, but the main reason for the increase of per capita carbon emissions is the insufficient support of the Guangxi government for green science and technology innovation; ④ The proportion of the secondary industry has a significant effect on the total carbon emissions and per capita carbon emissions, and the optimization of the city's industrial structure is conducive to the reduction of carbon emissions. Therefore, the Guangxi government should promote the successful experience of new energy demonstration cities, expand the scale of new energy demonstration cities, develop new energy in other cities according to local conditions, and effectively reduce carbon emissions in Guangxi.

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