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Research on the Stage of Regional Low-Carbon Economy Development, Influencing Factors and Policy Effects—Evidence from Jiangxi Province

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Abstract. This paper considers the pilot policy of low carbon cities as a "natural experiment". Firstly, the EKC curve is plotted using panel data of Jiangxi Province and eight prefectural-level cities in the province from 2010 to 2018, and it is judged that Jiangxi Province's economy is still in the rising part of the left side of the curve, and economic development is still occurring at the cost of carbon emission growth. Secondly, fixed-effects model was used to investigate the factors that influence CO_2 emissions, and it was discovered that industrial structure and the intensity of environmental management had an impact on carbon emissions. Thirdly, the Difference-in-Differences model is applied to evaluate the effect of low carbon city pilot policies, and it is discovered that the policies have a positive effect on energy conservation and emissions reduction. Finally, based upon the empirical results, suggestions for the future development of a low-carbon economy in Jiangxi Province are made in three areas: low-carbon production, environmental governance and supervision, and policy radiation.

1 Introduction

Jiangxi Province, as an important development and environmental protection area in China, is dealing with the dual pressures of economic development and environmental protection in its growth. In the early days, Jiangxi Province's growth policy followed the old road of development before governance, neglecting the establishment of a low-carbon economy. In 2010, the National Development and Reform Commission issued the Announcement on the Piloting of Low-Carbon Provinces and Low-Carbon Cities and launched three batches of low-carbon pilot cities one after another. The construction of low-carbon cities shows a progressive development path from pilot to gradual proliferation [1]. Based on this, it is particularly important to further deepen the research on the development of low-carbon economy and the effect of low-carbon policy implementation in Jiangxi Province.

2 An Empirical Study on the Environmental Kuznets Curve

2.1 Indicator selection and model construction

In this paper, CO_2 emissions in Jiangxi Province is chosen as an indicator of the degree of environmental impact and use GDP per capita in Jiangxi Province as an explanatory variable. The general form of the environmental Kuznets curve is constructed

$$CO_2 = \beta_0 + \beta_1 GDPP + \beta_2 (GDPP)^2 \tag{1}$$

Where GDPP is Jiangxi Province's GDP per capita, CO2 is Jiangxi Province's CO_2 emission, with its formula being primarily expressed by the product of Jiangxi Province's major energy consumption and its carbon emission factor:

$$CO_2 = \sum E_i * NVC_i * CEF_i * COF_i \tag{2}$$

where i represents an energy type, E represents the consumption of the ith energy source, *NCV* is the average net calorific value of the ith energy source provided in the annex of the China Energy Statistics Yearbook, *CEF* (kg/TJ) is the carbon emission parameter of the ith energy source provided by IPCC (2013), and *CFO* is the carbon oxidation factor of the ith energy source.

2.2 Modeling Results

Based on the statistical data of GDP per capita and CO_2 emissions in Jiangxi Province from 2010 to 2018, with GDP per capita and its square as the independent variable and CO_2 emissions in Jiangxi Province taking the natural logarithm as the dependent variable, the regression results of the environmental Kuznets curve model for CO_2 in Jiangxi Province were obtained using stata15 as follows.

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Table1. Fitted Coefficients of CO_2 EKC Curves in Jiangxi Province

Explained Variables CO_2	Coefficient	Std.Error	t-Statistic	Prob.
β_1	5155.808	671.0224	7.68	0.000
β_2	-0.048557	0.0127745	-3.8	0.003
β_0	52470000	7666477	6.84	0.000

The shape of the curve between CO_2 emissions and GDP per capita in Jiangxi Province from 2010 to 2018 resembles an "inverted U-shaped" relationship. It is demonstrated that there is a natural Kuznets curve relationship for carbon emissions in Jiangxi Province. Since the inflection point of Jiangxi's per capita GDP needs to reach RMB 53,090.265 per capita, Jiangxi Province is still in the left half of the curve, and is in a continuing upward trend, which has not yet reached the turning point. It indicates that the curve of the relationship between average CO_2 emissions and per capita GDP in Jiangxi Province has not yet entered the late industrialization development stage of the environmental Kuznets curve.

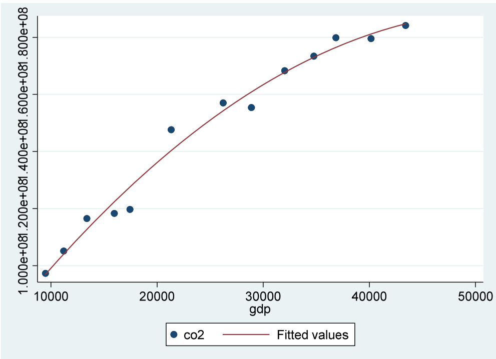

Figure 1. Fitted EKC Curve of CO2 in Jiangxi Province

3 Fixed effects model of the factors influencing CO_2 emissions

3.1 Model Building

Considering the province's growth features, this paper uses the share of secondary industry and the intensity of environmental management as the key explanatory indicators to investigate the influencing variables of CO_2 emissions in Jiangxi Province. The share of secondary industry represents a region's level of industrial growth. In general, the higher the share of industry, the more serious the carbon emission. Green production, on the other hand, may be able to replace the original energy-intensive businesses, lowering carbon emissions. Furthermore, the region's level of environmental governance intensity can represent the province's determination and ability to establish a low-carbon economy, which has an impact on CO_2 emissions. This paper included the number of year-end resident population, gross regional product, total energy consumption, R&D investment in science and technology, the number of governance facilities, and foreign direct investment as control variables in addition to the main explanatory variables. The initial econometric model was constructed as follows：

$$CO_{2it} = \alpha_0 + \alpha_1 IS_{it} + \alpha_2 GI_{it} + \alpha_3 X_{it} + \varepsilon_{it} \qquad (3)$$

where CO_2 is the CO_2 emissions of each municipality, *IS* is the share of secondary industry, *GI* is the intensity of environmental management, *X* is the relevant control variable, and ε is the random disturbance term of the model. The detailed variables are described as follows:

Table2. Variables

Type	Symbol	Variable Name	Representative Indicators	Symbol prediction
Explained Variables	CO_2	Carbon Dioxide Emissions	Total Carbon Dioxide Emissions	
Explanatory Variables	IS	Industrial Structure	Share of secondary industry in GDP	+ (-)
	GI	Environmental Management Intensity	Number of exhaust gas treatment equipment	-
Control Variables	GDP	Economic Scale	Regional Gross National Product	
	POP	Population Size	Regional Resident population	
	ES	Energy Consumption	Total Energy Consumption	
	TEC	Technology Level	Investment in Science and Technology by Public Expenditure	
	FIP	Foreign Investment Level	Amount of Foreign Investment Directly Utilized	

3.2 Data sources

This research examines panel data of eight prefectural-level cities in Jiangxi Province from 2010 to 2018. The consumption of various types of energy is based on the

Jiangxi Province Statistical Yearbook (2010-2018); indicators such as energy emission coefficients are based on the China Energy Statistical Yearbook and IPCC (2013); and the number of year-end resident population is based on the China Energy Statistical Yearbook and IPCC (2013), the number of year-end resident population, gross regional product, share of secondary industry structure, investment in science and technology R&D, number of governance facilities, and the amount of foreign direct investment in each city are obtained from the CENSUS City Statistical Yearbook (2010-2018).

3.3 Empirical results

Based on the panel data of eight cities in Jiangxi Province, the empirical analysis of Model 1 and Model 2 was conducted using stata. The original hypothesis that there is no systematic difference between random effects and fixed effects should be rejected based on the results of the Hausman test, implying that the fixed effects model is more effective. Therefore, in this paper, a fixed-effects model with panel data is applied to estimate the influencing factors of CO_2 in Jiangxi Province, and the final results are as following:

Table3. Table of fixed effects model coefficients

Explanatory Variables	Coefficient	z value	Prob.
IS	-0.1556229	-3.81	0.000
GP2	-0.0016909	4.30	0.000
GDP	-3.48e-7	6.20	0.000
POP	4.30e-7	-7.97	0.000
ES	0.00492373	-4.54	0.000
TEC	5.66e-6	0.8	0.424
FIP	-2.96e-0.6	-0.28	0.779
cons	11.19594	7.81	0.000

In terms of explanatory variables, the coefficient of the industrial structure variable is negative and significant at the 1% confidence level, indicating that the introduction of industry in Jiangxi Province is primarily green production enterprises, and the former industrial enterprises have been replaced by related low-pollution firms, low-carbon production has become the trend in secondary industry. The environmental management variable's coefficient is likewise negative and significant at the 1% confidence level, indicating that the establishment of environmental management and exhaust gas treatment facilities in Jiangxi Province reduces carbon emissions significantly.

From the control variables, GDP, population size and total energy consumption also have a significant effect on CO_2 emissions. Among them, the level of economic development has a suppressive effect on the level of carbon dioxide emissions in the region, and economic growth can bring a positive effect on the full development of a low-carbon economy. The rise in the number of residents will result in an increase in carbon emissions from living and production, making it more difficult for Jiangxi Province to establish a low-carbon economy. Carbon emissions will rise as overall energy consumption rises, indicating that Jiangxi Province continues to rely on high-carbon-emitting fossil fuels as its main source of energy.

4 Difference-in-differences model

4.1 Model Setting

The purpose of this paper is to assess the impact of low carbon city pilot policy on CO_2 emissions in Jiangxi Province. Because the first batch of low carbon pilot policy is mainly at the provincial level and only one city level in Nanchang City, and the third batch of low carbon pilot policy was implemented in 2017 with a time lag, the policy effect may not yet appear. Therefore, the second batch of low-carbon cities in 2012, Jingdezhen and Ganzhou, are employed as an experimental group. By comparing the CO_2 emissions of the experimental group (pilot areas) with those of the control group (non-pilot areas) before and after the low carbon pilot policy, and excluding factors that do not change over time and are not observable, the effect of the low carbon pilot policy on carbon emissions is reasonably assessed. The econometric model is established as follows:

$$CO_2 = \beta_0 + \beta_1 treat + \beta_2 year + \beta_3 year * treat + \sum \rho Control + \lambda_t + \sigma_c + \varepsilon \quad (4)$$

Within the model, CO_2 is the CO_2 emission of the city in year t. Treat is the pilot city dummy variable, if the city is a pilot city, it is "1", and vice versa, it is "0". *year* is the policy time dummy variable, after 2012, it is "1", and vice versa, it is "0"; The coefficient of year × treat is the cross product of treat and year, and its coefficient β3 is the policy effect that is the most concerned in this paper; Control is a series of control variables; λt, σc are the fixed effects of time and city fixed effects; ε denotes the random disturbance term [2].

4.2 Empirical Analysis

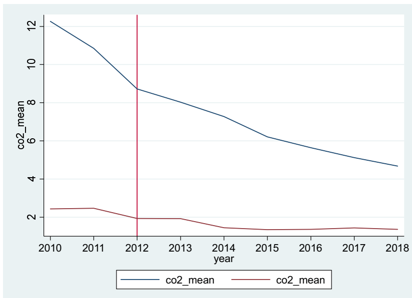

Figure 2. Parallel Trend Chart

The Difference-in-Differences parallel trend graph shown above demonstrates the year on the horizontal axis and the average value of CO_2 emissions on the vertical axis. Using the second batch of low-carbon pilots issued in 2012 as a dividing line, the pilot regions are generally greater than the non-pilot regions with time change in the non-pilot period (2010-2012), but they roughly show parallel patterns. And the pattern of change is consistent: during the pilot period (2013-2016), CO_2 emissions in low-carbon pilot areas fell rapidly. As a result, the parallel trend of Difference-in-Differences hypothesis is correct. The following are the results of the Difference-in-Difference model:

Table4. Difference-in-Differences Results

Variables	Coefficient	z value	Prob.
year × treat	-4.586	-2.02	0.049
GI	-0.011	-2.54	0.014
GDP	-2.86e-7	0.49	0.629
POP	2.85e-5	0.80	0.425
ES	-0.1544	-2.08	0.043
TEC	-7.68e-0.6	-0.21	0.835
FIP	-4.84e-5	-0.77	0.447

The regression results of the double difference model with the inclusion of time and city fixed effects show that the coefficient of year×treat is negative and significant at the 5% level, which indicates that the low-carbon city pilot policy has an energy-saving and emission-reducing effect on CO_2 emissions in Jiangxi Province. The environmental governance has a substantial impact on emission reduction outcomes as well. The more intense environmental governance is, the more obvious the effect of emission reduction policies becomes.

5 Research conclusions and policy recommendations

5.1 Research conclusion

Based on the environmental Kuznets curve theory, this paper first verifies the relationship between economic development and carbon emissions in Jiangxi Province, concluding that carbon emissions and economic development in Jiangxi Province are essentially in line with the "inverted U-shaped" relationship of first growth and then reduction. The calculation of the inflection point shows that Jiangxi's GDP per capita needs to reach 53,090.265 RMB when CO_2 emissions are decreasing. Jiangxi Province is still in the left half of the curve, continuing its upward trend, and has not yet reached the turning point.

Then, the fixed-effects model is used to investigate the major elements that influence each city's CO_2 emissions. The coefficient of industrial structure variable is negative, indicating that the introduction of industry in Jiangxi province is now primarily green production enterprises, with former industrial enterprises being replaced by relevant low-pollution enterprises, and low-carbon secondary industry production has become a trend. At the same time, the environmental governance variable's coefficient is negative, reflecting the fact that the results of the current environmental management in Jiangxi Province are beginning to show results .

Finally, the empirical evidence shows that the coefficient of year×treat is negative and significant at the 5% level, indicating that the low carbon city pilot policy can significantly reduce CO_2 emissions in Jiangxi Province, using a Difference-in-Differences model with the inclusion of time and city fixed effects for regression.

5.2 Policy Recommendations for Low Carbon Economic Development in Jiangxi Province

(1) It is advisable to optimize the industrial structure, realize the transition from high-polluting to low-carbon green production, and promote clean manufacturing [3]. At present, the environment-friendly industries in the Jiangxi Province region of China are in the development stage. It is necessary to improve environmental supervision and regulation to provide impetus for the development of environment-friendly industries.

(2) Strengthening the intensity of environmental governance and regulation to reduce carbon emissions. On the one hand, accelerate the construction of carbon emission governance facilities to promote the sustainable development capacity of Jiangxi Province [4]. On the other hand, in order to encourage the sound growth of a low-carbon economy, tighten legislation linked to sustainable development and raise the intensity of law enforcement.

(3) Low-carbon pilot cities, as an important regional economic development policy, have a higher positive influence on energy saving and emission reduction in Jiangxi Province . To support the transformation and upgrading of Jiangxi Province's total low-carbon economy, it is vital to fully utilize the radiation impact of the pilot cities.

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