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An Empirical Study on the Impact of Green Finance Development on Urban Carbon Productivity

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Abstract: *Based on the panel data of 282 Chinese cities from 2014 to 2022, this paper conducts an empirical analysis of the impact of green finance development on urban carbon productivity by constructing a difference-in-differences model. It is found that the implementation of green finance policy promotes the improvement of urban carbon productivity; Green finance policy has a positive effect on urban carbon productivity by promoting green technology innovation, improving energy structure and environmental protection willingness. The effect of green finance policy on carbon productivity is mainly reflected in non-resource-based cities. Therefore, it is suggested to widely implement pilot policies of green finance reform, actively guide financial institutions to gradually transfer to green finance and carbon sink finance business, and guide substantial green technology innovation to promote urban low-carbon transformation.*

Keywords: *Pilot Reform and Innovation of Green Finance; Carbon Productivity; Differential Model; Carbon Reduction*

1. Introduction

At present, in order to realize the harmonious development of real economy and ecology, the concept of low-carbon economy has gradually become an important idea for the sustainable development of human civilization. As the blood of the real economy, finance is crucial to the development of green economy. Therefore, green finance has become a specific measure to practice the development of low-carbon economy. Green finance policies, including green credit, green bonds, green insurance and other financial means, support the green transformation of polluting enterprises in various provinces with green finance policies, and encourage cleaner production to become the task goal of the manufacturing industry [1]. In this context, it is of both theoretical and practical significance to study whether green finance with green attributes and encouragement means can trigger significant carbon emission reduction effect for the promotion of related policies of green finance in China and the future green and high-quality development of China's economy.

The existing research at home and abroad is mainly carried out from the following aspects: First, the research on green finance and carbon emissions. In the early stage, most scholars studied from the dimension of financial development. Dasgupta et al. (2002) found that the improvement of financial development promoted the expansion of production scale and thus led to the increase of carbon emissions, that is, financial development had the effect of promoting carbon emissions [2]. Shahbaz et al.(2013) pointed out that there is a long-term equilibrium relationship between the improvement of financial development level and the reduction of per capita carbon emissions [3]. However, Dogan and Seker(2016) believe that the impact of financial development on carbon emissions is not linear, but shows an inverted U-shaped relationship [4]. Subsequently, on the basis of certain development of the total amount of finance, attention has been paid to the quality of financial development, and scholars began to pay attention to the emerging field of finance, namely green finance. The literature mainly studies the implementation effect of green financial policies and the application effect of various green financial instruments. The implementation of green finance policy effectively inhibits air and water pollution (Cai H.J. et al., 2019 [5]; Huang and Zhang, 2021 [6]). Green credit can reduce pollution emissions by promoting environmental protection transformation and technological upgrading of manufacturing industry (Jiang H.L. et al., 2020 [7]). Second, financial resource allocation and carbon emission reduction. Zhou Y.J. and Ji P. (2019) indicated that the improvement of financial resource

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allocation efficiency can significantly reduce carbon emissions, and this effect is more obvious when it is interconnected with the secondary industry [8]. Third, environmental regulation and carbon reduction. Sun S.S. et al. (2021) pointed out that environmental regulations have significant regional heterogeneity on carbon emissions in different regions, and the impacts of different types of environmental regulations are also quite different in different regions [9].

To sum up, existing literature has carried out detailed research on the relationship between green finance, financial resource allocation, environmental regulation and carbon emission reduction, which provides a solid foundation for this study. At the same time, by reviewing the literature, we can find that there are few studies on the impact of green finance on urban carbon productivity. Based on this, this paper expands the existing research as follows: First, based on the panel data of 282 Chinese cities from 2014 to 2022, an empirical analysis is carried out using the difference-in-differences model. Second, the pilot policy of green finance reform and innovation is taken as a quasi-natural experiment to investigate the impact of green finance development on urban carbon productivity. Thirdly, the heterogeneity test of resource-based and non-resource-based cities is further conducted according to the classification standard of resource-based cities.

2. Description of variables and data sources

2.1. Variable description

2.1.1. Explained variables

In this paper, urban carbon productivity (CP) was selected as the explained variable, the natural logarithm of gross product per unit carbon emission was used to represent carbon productivity, and the consumption of coal, coke, crude oil and natural gas in each region was selected to calculate carbon emission in each region.

2.1.2. Explain variables

In this paper, pilot policy of financial innovation reform (DID) is selected as explanatory variable, which is dummy variable.

2.1.3. Mechanism variables

In this paper, the number of green technology patents applied by cities over the past years is selected as the characteristic variable of green technology innovation. The proportion of coal consumption in total urban energy consumption was used as the characteristic variable of energy structure (strcoal), and the comprehensive utilization rate of solid waste of industrial enterprises in each city was used as the characteristic variable of environmental protection intention (Env).

2.1.4. Control variables

In this paper, per capita GDP (lnpGDP), manufacturing output value ratio (strind), population density (popden) and hydropower generation ratio (lnslfd) were selected as control variables.

2.2. Data sources

Table 1: Descriptive statistics of variables.

Variable class	Sample size	Mean value	Standard deviation	Min-value	Max-value
Green finance reform and innovation pilot zone policy variables	3892	0.067	0.232	0.000	2.000
Urban carbon productivity	3892	0.473	0.405	0.043	2.489
GDP per capita	3892	12.365	0.872	7.881	14.296
Share of manufacturing output	3892	0.378	0.213	0.017	0.893
Population density	3892	1.872	0.231	13.192	13.147
Proportion of hydroelectric power generation	3892	0.248	0.147	0.000	0.916

The research objects of this paper are 282 prefecture-level cities in China. The data mainly come from China Regional Economic Statistical Yearbook and China City Statistical Yearbook from 2014 to 2022, and are supplemented by the statistical bulletins of cities over the years and statistical yearbooks

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of provinces. Considering the interference caused by inflation to the estimated results, data related to the output value in the paper are adjusted according to the constant price of 2014. In addition, in order to prevent the interference caused by outliers in the data, the main indicators are indented at the quantile level of 1% and 99%. The relevant statistical descriptions are shown in Table 1.

3. Empirical analysis

3.1. Measurement model setting

In order to verify the relationship between the establishment of green finance reform and innovation pilot zones and urban carbon emissions, this paper builds the basic model as follows:

$$CP_{it} = \alpha_0 + \alpha_1 DID_{it} + \alpha_2 X_{it} + \varepsilon_t + \varepsilon_i + \varepsilon_{it} \quad (1)$$

Where, i represents the city, t represents the year, CP_{it} is the explained variable, represents the city carbon productivity, DID_{it} represents the policy effect of the green finance reform and innovation pilot zone, α_0 and X_{it} represents the constant term and control variable, ε_t and ε_i represents the city fixed effect and time fixed effect, ε_{it} is the residual term.

3.2. Analysis of benchmark regression model

In order to explore the impact of green finance development policies on urban carbon emissions, benchmark regression analysis was conducted, and secondary analysis was conducted without control variables and by adding a series of control variables. The regression results are shown in Table 2.

Table 2: Regression results of green finance reform and innovation pilot zone on urban carbon productivity.

Variable	(1)	(2)	(3)
	CP	CP	CP
DID	0.114***	0.127***	0.146***
lnpGDP		0.044	0.042***
strind		0.058***	0.053***
popden		0.094***	0.107***
lnslfd		0.024***	0.028***
Constant term	1.379***	1.236***	1.458***
Observed value	3892	3892	3892
Time-fixed effect	No	No	Yes
Urban fixed effect	No	No	Yes
R^2	0.8964	0.8317	0.8679

Note: ***, ** and * are significant at the 1%, 5% and 10% levels respectively.

In Table 2, columns CP (1) and CP (2) respectively show the results of baseline regression analysis without and after control variables are added. DID coefficients of variables are significant. Therefore, it can be concluded that the implementation of green finance policy can significantly improve the carbon productivity of cities.

3.3. Parallel trend hypothesis test

Table 3: Test results of parallel trend hypothesis.

Argument	G
year 2014	0.035
year 2015	0.047
year 2016	0.068
year 2017	0.076
year 2018	0.084
year 2019	0.093
year 2020	0.107**
year 2021	0.113**
year 2022	0.122**

Note: ***, ** and * are significant at the 1%, 5% and 10% levels respectively.

In order to further validate the validity of the differential model, this paper conducts parallel trend

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test for cities in the green finance reform and innovation pilot zone and cities in the non-green finance reform and innovation pilot zone, and the results are shown in Table 3.

As can be seen from Table 3, the coefficient of the interaction term shows an insignificant state before 2020, and a significant positive effect in the following three years. Therefore, it can be concluded that the implementation of pilot policies of green finance reform and innovation can improve urban carbon productivity and meet the requirements of parallel trend test on the whole.

3.4. Robustness test

In this paper, the PSM test and DID test were combined, and the practice of Shi Daqian et al. (2018) was used for the quantitative test of policy dummy variables and control variables [10]. The logit model was adopted to divide the samples with similar scores into the same group. As can be seen from Table 4, there is a small gap between the regression results and the above, indicating the robustness of the empirical results.

Table 4: Results of balance test

Robust approach	PSM+DID
DID	0.168**
hdid	
Control variable	Yes
Time-fixed effect	Yes
Urban fixed effect	Yes
Observed value	3629
R^2	0.6679

Note: ***, ** and * are significant at the 1%, 5% and 10% levels respectively.

3.5. Mechanism test

The results of the benchmark regression model verify the promoting effect of green finance development on urban carbon productivity. In order to further explore the promoting mechanism of green finance development on urban carbon productivity, the variables of green technology innovation, energy structure improvement and environmental protection intention are included in the regression model, and the following model is established:

$$M_{it} = \beta_0 + \lambda DID_{it} + \beta_2 X_{it} + \varepsilon_{it} \tag{2}$$

$$CP_{it} = \beta_0 + \varphi_1 M_{it} + \beta_2 X_{it} + \varepsilon_{it} \tag{3}$$

Where, M_{it} represents the mechanism variable. Equation (2) tests the influence of core variable on the three mechanism variables, and Equation (3) tests the influence of mechanism variable on the explained variable. See Table 5 for specific results.

Table 5: Mechanism test results.

Variable	Innovation	CP	Strcoal	CP	Env	CP
DID	0.132***	0.215***	0.158***	0.204***	0.312***	0.401***
Innovation		0.268***				
Strcoal			0.086***	0.085***		
Env						0.198***
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Time-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Urban fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observed value	3892	3892	3892	3892	3892	3892
R^2	0.3549	0.3894	0.2093	0.2153	0.3457	0.3794

Note: ***, ** and * are significant at the 1%, 5% and 10% levels respectively.

It can be seen from the regression results of column 1, 3 and 5 in Table 6 that green finance development has a significant effect on the three mechanism variables of green technology innovation, energy structure improvement and environmental protection intention. According to the regression results of Column 2, 4 and 6, green technology innovation, energy structure improvement and environmental protection intention enhancement all significantly affect urban carbon productivity.

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3.6. Heterogeneous type analysis

In this paper, according to the classification standard of resource-based cities, the selected cities are divided into resource-based cities and non-resource-based cities, and the regression test is carried out respectively. The results are shown in Table 6.

Table 6: Results of heterogeneity analysis

Variable	Resource-based city	Non-resource-based city
DID	0.172^{***}	0.217^{***}
Observed value	1732	2160
Time-fixed effect	Yes	Yes
Urban fixed effect	Yes	Yes
Control variable	Yes	Yes
R^2	0.8023	0.8149

Note: ***, ** and * are significant at the 1%, 5% and 10% levels respectively.

The empirical results in Table 6 show that, compared with resource-based cities, the carbon productivity of non-resource-based cities is more strongly influenced by green finance policies. The possible reason is that clean industries in non-resource-based cities account for a larger proportion. This indicates that non-resource-based cities have more green investment projects and are easier to cooperate with green finance institutions. In turn, it will help improve the carbon productivity of non-resource-based cities.

4. Conclusions and suggestions

4.1. Conclusions

This paper takes the pilot policy of green finance reform and innovation as a quasi-natural experiment to explore the impact of green finance development on urban carbon productivity, and mainly draws the following conclusions: First, it can be concluded from the influence of independent mechanism that green finance can effectively promote the improvement of urban carbon productivity. Second, it can be seen from the regression results of mechanism test that green technology innovation, energy structure improvement and environmental protection intention enhancement play a positive conduction role between green finance policy and urban carbon productivity. Third, it can be seen from the heterogeneity test results that the pilot policy of green finance reform and innovation has a more significant effect on the carbon productivity of non-resource-based cities.

4.2. Suggestions

Based on the above empirical research and conclusions, this paper puts forward the following policy suggestions:

First, we will actively promote the experience of pilot projects and accelerate the development of a sound green finance system. To improve the construction of green finance system, the government needs to make continuous efforts, speed up the formation and improvement of the corresponding policy system, give full play to the effect of green finance pilot policies, realize coordinated promotion between the government and the market, create new channels for green investment and financing, enhance the combined role of green investment by the government and green financing by financial institutions, and fully tap and bring into play the huge potential of green finance.

Second, the government should guide financial institutions to gradually transform to green finance and carbon sink finance. The key is to improve the development policy system of green finance and the formulation of relevant industry standards, through professional green finance operation mode, management and credit review methods, to standardize the evaluation system of green and low-carbon investment projects, and promote the development of manufacturing enterprises in the direction of green.

Third, we will encourage substantive green technology innovation. When formulating the measures to increase credit and divide risks by green, the government should refine them according to the innovation and potential value of green technology projects, guide financial institutions to research and develop green technologies with high technology content, increase medium - and long-term financial

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support, and promote enterprises to carry out substantive green innovation. At the same time actively launched "carbon footprint" linked floating rate loan products.

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