



Does Green Finance Influence Regional Carbon Emission Intensity? Evidence from China

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Abstract. Green finance is crucial to mitigate carbon emission intensity. However, the existing researches barely consider its practical effect and the transmission mechanism. Using sample data of 30 provinces in China for the periods 2016–2019, this paper incorporates a comprehensive index system and more accurate amounts of carbon emissions into measuring green finance and carbon emission intensity. Based on that, the research constructs the OLS regression model and fixed-effect model to analyze the carbon reduction effect of green finance from two aspects: whole and regional. The empirical results demonstrate that green finance has an overall significant influence on abating carbon emissions in China. Additionally, green finance in pilot zones for green finance reform and innovations lessens carbon emissions intensity more visibly than that in non-pilot areas. The study finds that the establishment of the pilot zones arouses local government’s concern about the reform of green finance and promotes more effective implementation of green finance policies. In addition, compared with western and central economic regions, the development of green finance in eastern economic areas has a higher correlation with the curb of carbon emissions. Hence, green finance’s actual impact on carbon reduction is related to regional characteristics, especially economic conditions. These findings are essential for policy-makers to cut down on carbon emissions at the local level.

Keywords: Green Finance · Carbon Emission Intensity · Empirical analysis

1 Introduction

With the aggravation of global warming, taking active measures to alleviate emissions of greenhouse gases, especially carbon dioxide, is a top priority for the globe. China is not an exception. According to Paris Accord, the carbon dioxide emission in China was expected to peak around 2030. In 2020, China further committed to achieving carbon neutrality before 2060. These ends put forward an urgent need for China to transit and upgrade the economic development model. Therefore, the concept of “Green Development” was first introduced in the 13th Five-Year Plan, making green finance a crucial part of promoting the progress of green development. To explore a path of green finance development suitable for China, since June 2017, the State Council has set up

nine “pilot zones for green finance reform and innovations” in six provinces involving Zhejiang, Jiangxi, Guangdong, Guizhou, Gansu, and Xinjiang, respectively. This action marks China’s beginning to comprehensively advance the development of green finance at the local level.

Guidelines for Establishing the Green Financial System issued by the People’s Bank of China defined green finance officially for the first time. It refers to financial services for economic activities that support environmental improvement, climate change mitigation, and more efficient resource utilization. At the end of 2021, China’s outstanding green loans reached 15.9 trillion yuan, with year-over-year growth of 33%, ranking first worldwide. Meanwhile, the scale of green bonds issued by RMB kept increasing, diversified green finance products emerged, and the national carbon emissions trading market launched online trading. The development of green finance in China is in full swing. But whether the development of regional green finance helps mitigate local carbon emission intensity lacks empirical research.

With the increasing development of green finance, there is a growing literature focusing on the relationship between green finance and carbon emissions. In general, previous empirical studies are from two perspectives. One of them focuses on whether China’s current green finance policies have their ways. The other pays attention to the effect of specific instruments of green finance on carbon-emission reduction.

Du and Zheng teased out how China’s green finance policy system formed and divided the process into four phases. Taking pilot policy of carbon emissions trading as the subject, they examined the effectiveness of green finance policy on carbon emissions in pilot zones using the Differences-in-Differences (DID) model. Their empirical results imply that the implementation of the pilot policy of carbon emissions trading is accompanied by apparent decreasing carbon emissions in pilot areas [1]. Fan et al. explored how green credit regulation influences corporates’ loan conditions, affecting their production scale and environmental quality. Empirical findings indicate that the green credit policy, attempting to integrate the ecological credit risk of borrowing firms into the loan conditions, has a distinctive effect on pollution reduction [2].

Huang et al. viewed technological innovation as a mediating variable and analyzed the impact of green investment on CO₂ emissions of 30 provinces in China from 1995 to 2019. The results of the CS-ARDL approach show that through accelerating technological innovation, green investment abates CO₂ emissions in China [3]. Tian et al. used grey system theory and information entropy to investigate the correlation between the financial environment and carbon markets. By classifying green financial tools into direct and indirect funding, the research eventually finds that direct financing, including green bonds, green funds, and green trusts, affects carbon-emission reduction more definitely than indirect funding, especially green credit provided by banks [4]. Nevertheless, Jiang et al. have a contrary empirical finding in the statistics of China’s 23 provinces from 2006 to 2016. They measured green finance by the representative proxies of green credit and green venture capital. Through the dynamic panel regression model, they saw that both the two green financial instruments could curb carbon emissions separately. However, when two green financial instruments simultaneously acted in one model, except for the group of low-carbon emission provinces, the coefficient of green venture capital in all

regions and the group of high-carbon emission provinces is no longer apparent. The consequence suggests that green credit has a more substantial carbon reduction effect than green venture capital [5]. These findings are confirmed by You et al., who conducted a similar study using sample data of 30 provinces in China from 2009-to 2019 and added the green bond into the index system. The dynamic regression result implies that the coefficient of the green bond is small and shows insignificant, while the other two variables are significantly and negatively correlated with carbon emissions. According to the study, the differences in actual function might be because green credit has the earliest start and the largest scale among all sorts of green finance services in China. Furthermore, despite later start, green venture capital with bulk investment greatly promoted the development of green industries under the government's instruction. Even though green bond has policy support, the short public issue time, small scale, and incomplete rule system adverse green bond's carbon-emission reduction [6].

This research intends to determine whether the implementation of green finance policy practically works in mitigating carbon emission intensity, not only from the view of the whole country but also at the local level. The exploration provides an empirical and scientific basis for China's formulation and implementation of green finance policies. This paper, to begin with, builds a static regression model to examine the relationship between carbon emission intensity and the performance of green finance policy. Then, the study applies the fixed effect model to investigate if the result of green finance in pilot zones for green finance reform and innovations differs from that of non-setting areas, and uses the same approach to examine the discrepancy in the performance of green finance among three major economic regions.

2 Method

2.1 Data Sources

The research collects data from 30 observations of provinces and autonomous regions in China over the four-year period:2016–2019. In consideration of data's availability, reliability, and comparability, the sample excludes Tibet due to data missing. It also eliminates Hong Kong, Macao and Taiwan because they are at different stages of development in green finance from that on the mainland.

The index measuring the development effect of the regional green financial market was obtained from the annual Index and Report of Provincial Green Finance Development published by the Central University of Finance and Economics. Carbon emission of each region was collected mainly from Carbon Emission Accounts and Datasets (CEADs). Other relevant socio-economic data at the province level was supplemented by the National Bureau of Statistics of China.

2.2 Variable Description

2.2.1 Independent Variable

Regional carbon emission intensity ($LnCEI$), referring to the ratio of annual carbon dioxide emission (in tons of carbon dioxide) of each province to its annual gross domestic

product (GDP, in units of 100 million RMB), is used to measure the carbon emission corresponding to per unit GDP of each region. Since both regional carbon emission and energy consumption are essentially correlated with the size of a region's economy as well as the per capita GDP [7], compared with regional total carbon emissions and carbon emission density (per capita carbon emissions), regional carbon emission intensity (*CEI*) taking the socially determined aspect into account is much more representative and comparable. In order to make the data more stable and avoid problems caused by skew distribution and heteroscedasticity, the study selects the natural logarithm of regional carbon emission intensity (*LnCEI*) as the independent variable. The calculation formula is as follows:

$$LnCEI = \ln\left(\frac{Co_2}{GDP}\right) \quad (1)$$

2.2.2 Dependent Variable

Index of green finance development (*Score*). The measurement of regional green finance development in previous studies varies considerably, but constructing the indicator system through choosing one or several proxies ranging from the dummy variable describing whether introducing relevant green finance policy [1, 2] to the indicators representing the performance of green financial instruments, including green credit, green industrial investment, green bond market, green insurance, etc. [3–6] is a well-acknowledged approach. However, such an indicator system fails to examine the comprehensive performance of green finance appropriately because solely individual financial markets are involved.

Fortunately, the International Institute of Green Finance (IIGF), Central University of Finance and Economics, has published the Index and Report of Provincial Green Finance Development annually since 2018. These reports offer the only official and multi-dimension assessed figure to evaluate the development of green finance at the local level. The index system establishes the index of provincial green finance from two dimensions government intervention and market effect. [8]. Nevertheless, attributing to the inadequate policy implementation and underdeveloped financial sector, there's a remarkable difference between the Score of green finance policy and actual market practice in some provinces. In order to align the index setting with green finance practices in provinces, this paper constructs the modified index (*Score*) as the product of the Score that considers the market performance of regional green finance times the proportion of provincial output value of the financial industry in local GDP.

$$Score = Score_{mar} * FS \quad (2)$$

2.2.3 Control Variable

Level of regional opening-up (*LnFDI*). This index is the amount of foreign direct investment (FDI, in units of 100 million US dollars) after logarithmically transformed. China's industry, especially the manufacturing industry, has always been a key field of foreign

direct investment. Over the recent years, the utilization of foreign capital in the industry has been prone to transfer to high-tech industry [9]. Thus, this paper speculates that the higher the level of opening-up that a province has, the more favorable to introduce and conduct cross-border cooperation of clean production technology, a modified technology of the original production technology that mitigates or even eliminates the amount of pollution and toxicity.

Regional industry structure (*IS*) is measured as the percentage of the provincial output value of secondary industry concerning the local gross domestic product.

Regional ecological and environmental quality (*LnEnv*) is the natural logarithm of regional per capita availability of water resources.

The degree of regional government intervention (*LnGov*) refers to the natural logarithm of general public budget expenditure of local government (in units of 100 million RMB). Fiscal capacity ensures the thorough implementation of green finance policies.

The degree of regional urbanization (*Urb*) is indicated as the proportion of the urban population in the province's total population.

The speed of regional economic growth (GDP) is the GDP growth rate of each province.

2.3 Model Specification

The research takes regional carbon emission intensity (*LnCEI*) as the independent variable and the effect of regional green finance development (*Score*) as the dependent variable to analyze the impact that green finance had on carbon emissions by using the following static panel regression model:

$$LnCEI_{i,t} = \beta_0 + \beta_1 Score_{i,t-1} + \sum \delta X_{i,t} + \varepsilon_{i,t} \quad (3)$$

where *i* represents each region and *t* refers to the year. *LnCEI_{i,t}* is the logarithmic value of carbon emission intensity of province *i* in year *t*. In tune with Wang and Yang [8], the study adopts the evaluation cycle of the local green finance development index, from June, *t* - 1 year to June, *t* year. Thus, the *Score* acting as the core explanatory variable is supposed to be lagged one phrase to guarantee the causality of the relationship. *X_{i,t}* and $\varepsilon_{i,t}$ are the vector of control variables and random errors, respectively.

The descriptive results for each variable are shown in Table 1.

As the descriptive statistics presented in Table 1, the mean logarithm of regional carbon emission intensity is 7.176, varying between 5.516 and 8.642. Ningxia has the highest carbon emission intensity, and Beijing has the lowest one over the sample period. While in terms of carbon emissions, Shandong is the highest, and Hainan is the lowest during the sample period. The mean *Score* evaluating the effect of regional green finance development is 2.024, varying between 0.420 and 12.455. With the highest standard deviation among all variables, 1.872, the performance of green finance differs significantly between regions.

The sample data is present as short panel data ($N = 30, T = 4, N > T$), so theoretically, there's no need for the stationary test.

Table 1. Descriptive statistics of the selected data.

	Observations	Mean	Sd	Min	Max
LnCEI	120	7.176	0.668	5.516	8.642
Score	120	2.024	1.872	0.420	12.455
LnFID	120	6.397	1.333	3.358	9.053
IS	120	0.384	0.072	0.160	0.496
LnEnv	120	6.052	1.450	2.092	7.990
LnGov	120	8.565	0.547	7.135	9.758
Urb	120	0.617	0.108	0.446	0.892
GDP	120	0.090	0.032	0.009	0.212

Table 2. The results of the fixed-effect model

	All regions
L.Score	-0.071*** (0.018)
_cons	7.277*** (0.035)
Individual effect	Control
<i>N</i>	90
<i>R</i> ²	0.216
adj. <i>R</i> ²	-0.183

3 Results

The method of traditional ordinary least squares (OLS) was adopted to examine the multiple linear regression aiming at obtaining the coefficients of Eq. (3) at a different significant level (Table 3).

Regression results presented in Table 3 demonstrate that the Score has a statistically significant correlation with LnCEI at the 0.1% level, implying that green finance has negatively influenced carbon emission intensity in provinces of China, which is consistent with the theoretical expectation. The correlation coefficient shown in the Table 3 (5) suggests that each unit increase in the Score is associated with 0.149% lower carbon emission intensity (CEI) in regions.

This paper adds a fixed-effect panel regression model (Table 2) to ensure the robustness of the regression results presented in Table 3.

Notably, the estimated coefficients of the index of the green finance have a negative meaning at the 0.1% significant level, indicating green finance helps lessen the carbon emission intensity, which accords with the result of Table 3.

Table 3. The OLS regression results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	LnCEI	LnCEI	LnCEI	LnCEI	LnCEI	LnCEI	LnCEI
L.Score	-0.234*** (0.033)	-0.123*** (0.035)	-0.093* (0.040)	-0.125*** (0.034)	-0.149*** (0.034)	-0.182*** (0.040)	-0.162*** (0.044)
LnFID		-0.260*** (0.047)	-0.282*** (0.049)	-0.294*** (0.041)	-0.371*** (0.051)	-0.433*** (0.065)	-0.418*** (0.066)
IS			1.232 (0.798)	1.740* (0.674)	1.253 (0.687)	1.168 (0.684)	1.471* (0.735)
LnEnv				-0.184*** (0.030)	-0.236*** (0.036)	-0.211*** (0.039)	-0.208*** (0.040)
LnGov					0.303* (0.127)	0.383** (0.137)	0.334* (0.143)
Urb						1.291 (0.832)	0.913 (0.897)
GDP							-1.647 (1.474)
_cons	7.590*** (0.085)	9.071*** (0.278)	8.684*** (0.373)	9.737*** (0.357)	8.175*** (0.743)	7.032*** (1.042)	7.573*** (1.148)
N	90	90	90	90	90	90	90
R2	0.369	0.532	0.545	0.684	0.704	0.712	0.716
adj. R2	0.362	0.522	0.529	0.669	0.686	0.691	0.692

Note: Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, similarly hereinafter

4 Discussion

Based on multi-regression results, the research discovers that the development of regional green finance promotes regional carbon emission reduction in practices, which is identical to previous literature [1, 5, 6]. These findings confirm that the promotion of green finance is an indispensable factor that contributes to achieving carbon peaking and carbon-neutral targets. More importantly, China's reform of green finance has been evidenced to achieve preliminary success.

4.1 Variable Analysis

Six control variables included in this study act as helpful signs for green finance to direct the flow of capital.

Interestingly, according to Table 2, the coefficient of the level of regional opening-up is greater than that of the index of green finance development (*Score*) at the 0.1%

significant level, denoting that the employment of foreign direct investment weakens regional carbon emission intensity too, and even more beneficial than the green finance to some degree. This result contradicts the pollution haven hypothesis (PHH) while keeping with empirical results [10] that are relatively new in the existing research. This discovery proves that foreign direct investment is an effective way to cross the barriers of green and low-carbon technology, so it can also be served as a beneficial signal for financial institutions and market capital to invest in green and low-carbon projects. Additionally, Table 2 reflects that regional industry structure is positively correlated with carbon emission intensity. Compared to the primary and tertiary industries, the secondary industry, especially the electricity department, emissions much more carbon dioxides from energy consumption and industrial production processes. Thus, in light of this phenomenon, green finance enables capital to flow effectively to emerging green industries to restrain the blind expansion of projects with high energy consumption and high carbon emissions. Apart from this, it is revealed that regional environmental quality abates carbon emission intensity, signifying that green finance can play a role in carbon emission reduction by resolving the funding difficulty of ecological and environmental protection projects. Hence, areas with more emphasis on environmental governance might be more enthusiastic about developing regional green finance. Besides, government intervention is statistically significant at the 5% level with a positive coefficient (0.303), meaning that nationally, government intervention did not take an evident effect on the reduction of carbon emissions. The upsetting finding inspires local governments to center more on the regional development of green finance and carbon emission control in the future. Although the impacts of regional urbanization and economic growth are in line with expectation, the estimated p-value of each variable reveals insignificant here.

4.2 Importance and Influence Path Analysis

This section discusses why green finance is vital to developing the green economy and analyzes the influence path between green finance and carbon emission intensity.

Green finance acts as a financial policy and is a valuable source of funds to achieve the carbon-neutral goal. Carbon emissions are closely related to the structure of energy production and consumption. As is known to all, China has abundant coal reserves contributing to coal over-dependence in industrial manufacture and correspondingly large carbon emissions. It is predicted by Chen [11] that the investment needed to achieve the “dual carbon target” in China will cost about 68 trillion Yuan, mostly spending on the replacement of thermal power generation and fossil fuels with clean power, R&D of low-carbon technology and cleantech used to improve energy efficiency in traditional high-carbon emission industries and fossil fuel extraction field. The above shows that capital will be in great demand while carrying out the carbon reduction programs. However, the government’s financial support can merely cover a small part of the gap, and plentiful market funding is required to make up the shortfall, so green finance stepped in.

The carbon alleviating mechanism of green finance is performed as follows—first, optimizing the allocation of financial resources. Green credit provides covenant-lite loan support and preferential interest rates to enterprises striving to build a green economy and otherwise punishes high-polluting corporates on limited loans and high-interest rates. As a result, Productivity impairment occurs in high energy-consuming enterprises

when faced with financing restrictions, reducing carbon emissions. Correspondingly, the funding loaned to green and low-carbon corporates will rise, boost the eco-friendly production scale's expansion, and deepen pollution prevention. Second, encouraging and forcing the technology innovation of enterprise. Companies are encouraged and compelled to develop low-carbon technologies through differentiation monetary policy. Third, exerting signal transfer effect, with the development of green finance policy, evaluation standards of the microgreen finance system will be gradually improved. The ESG information of corporates will be transparent, providing a signal for financial institutions and social capital to pour in and policy-makers to institute appropriate economic policies.

4.3 Regional Discrepancy Analysis

Whereas, there is a conspicuous fluctuation in the regional performance of green finance, which might stem from the fact that the reform of green finance is still at the pilot stage at present and the objective difference existing among provinces in terms of geographical conditions, policy-making and economic power. This paper applies a fixed panel data model to make a dipper investigation.

As the results presented in Table 4, compared with Model (2), the index in the model (1) has a higher coefficient at the 5% significant level, and the R-square of Model (2) is up to 0.464 which is roughly triple of 0.16 in the model (1), indicating that the performance of green finance in the pilot zones has a more obvious impact on cutting down carbon emissions than in non-pilot zones. The lower significant level might be because the instruments of green finance used in green investment projects usually have a more extended payback period and a deferred effect.

The foundation of the pilot zones provides more policies to boost the regional green finance, reflecting that the measures taken by local governments are crucial to the practical effect of green finance. The positive result reflects that the exploration of establishing

Table 4. The results of the fixed-effect model

	Model (1)	Model (2)
	Pilot zones	Non-pilot zones
L.Score	-0.082* (0.027)	-0.066** (0.022)
_cons	7.362*** (0.066)	7.254*** (0.040)
Individual effect	Control	Control
<i>N</i>	18	72
<i>R</i> ²	0.464	0.160
adj. <i>R</i> ²	0.172	-0.269

Table 5. The results of the fixed-effect model

	Model (1)	Model (2)	Model (3)
	East	Central	West
L.Score	-0.052*** (0.012)	-0.195* (0.070)	-0.172* (0.076)
_cons	6.959*** (0.036)	7.571*** (0.084)	7.615*** (0.102)
Individual effect	Control	Control	Control
<i>N</i>	36	27	27
<i>R</i> ²	0.450	0.314	0.229
adj. <i>R</i> ²	0.163	-0.049	-0.179

pilot zones has gained a stage achievement. Thus, it is a viable scheme that is well-recommended to be employed in other provinces where the carbon emission intensity remains high.

Furthermore, the study examines the green finance development discrepancy among China's three major economic regions.

As the finding is shown in Table 5, the significance level of the coefficient and the R-square in the model (1) is the highest among all three models, implying that the advance of green finance in the eastern economic region is more related to the curb of carbon emission intensity. Eastern provinces have a relatively perfect financial market resulting in a smoother transmission effect, attributing to extensive emerging enterprises, high-tech industries and financial institutions. Advantages in the economic environment facilitate green finance services expanding scale and accommodating the funding demand for green projects more effectively, which causes the carbon reduction effect to be more remarkable. While the research and development in new energy utilization have lagged benefits, the resulting carbon reduction effect is limited. On the contrary, most corporations in central and western economic regions are small-scale enterprises whose demands for green credit are still low, and the financial systems there are underdeveloped, causing a lack of transactions in green financial businesses. So, the correlation between green finance and CEI is lower in these two areas.

Nonetheless, giant fossil fuel production provinces such as Ningxia, Xinjiang, Shaanxi, Gansu, etc. located in the western area and Anhui, Shanxi, Shaanxi, etc. situated in the central area all have a great transformation desire for the energy industry. The green finance businesses are helpful in effectively improving the local energy structure. Therefore, in models (2) and (3), green finance has a more substantial carbon-emission abatement effect.

5 Conclusion

This research considers static regression models to identify the impact of green finance on regional carbon emission intensity based on collected data from 30 provinces in

China from 2016 to 2019. The results show three relevant conclusions. First, as a whole, the findings show a positive relationship between green finance and ecological quality in China. The better performance regional green finance services have, the lower the regional carbon emission intensity will be. Second, regarding the impact of setting up “pilot zones for green finance reform and innovations”, this paper finds that compared with non-pilot zones, the performance of green finance in pilot areas affects carbon emissions intensity relatively more by spurring the local government to improve policy mechanisms for green finance. Third, the empirical results imply that the green finance businesses in the eastern economic region are more relevant to the carbon emission reduction than in western and central economic regions. In general, this paper finds that the effectiveness of green finance on carbon reduction is related to regional characteristics, especially economic conditions. The area with a more robust market system providing a better environment for advancing green finance tends to have a stronger desire to transit toward green and low-carbon development.

Based on empirical analysis, this paper proposes the following suggestions. First, this paper suggests that provinces introduce more supportive policies for developing regional green finance since it is beneficial for weakening carbon emission intensity. Second, the scheme of establishing pilot zones for green finance reform and innovations has its way. Therefore, it is well-recommended that other regions join the group and explore the self-suitable way to develop local green finance under the central government’s instruction. More importantly, due to the different regional characteristics, the formulation of regional green finance development planning should adapt to local development conditions to maximize the role of the green financial market. As the first country in the world where the central government leads local governments to explore the reform of green finance, China’s successful experiences are worth learning for countries in the hope of reducing their carbon emissions.

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