

Research on the Effect of Green Finance in Supporting Energy Conservation and Emission Reduction Under the "Carbon Neutral" Target-Evidence from China

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Abstract. Developing green finance and promoting it to support energy conservation and emission reduction is an important means to achieve the "carbon peak" and then achieve the "carbon neutral" goal in China. The panel data from 2009-2020 from various provinces in China were selected to discuss the effect and path mechanism of green finance on energy conservation and emission reduction. The results show that green finance can significantly reduce energy consumption and restrain carbon emissions, which helps to achieve energy conservation and emission reduction. Secondly, industrial structure upgrading and technological innovation transmit the influence of green finance to energy consumption through intermediary effect, producing energy saving effect. Finally, industrial structure upgrading also has an intermediary effect in the impact of green finance on carbon emissions. Based on the goal of "carbon neutral", it is suggested to improve the green financial system to improve the development level of green finance, vigorously promote the upgrading, transformation of industrial structure, and encourage the technological innovation of enterprises.

1 Introduction

Responding climate change is the biggest non-traditional security challenge facing the world today. At the 75th UN General Assembly, General Secretary firstly proposed the "two-carbon goal" of achieving carbon peak by 2030 and achieving carbon neutrality by 2060. Party's 20 report proposed to promote carbon reduction, pollution reduction, growth, promote green and low carbon development modernization. Green modernization is to innovate green elements, accelerate the implementation from high carbon economy to low carbon economy, create green financial system is given priority to with consumption reduction, achieve zero carbon or carbon neutral, creating the biggest green well-being of their livelihood at the same time, make greater green contribution to the global response to climate change. As a green finance and an effective means of resource allocation integrating the dual forces of policies and markets, green finance is a continuous driving force for the realization of the goal of "carbon neutrality", boosting the green transformation, green development, low-carbon development and circular development of enterprises, industries and the whole society, and forming a modern green economy system. This paper focuses on the goal of "carbon neutral", starting from the transmission mechanism of green finance on energy conservation, consumption reduction and emission reduction, and explores the effect and support path of green finance to support the realization of energy conservation and emission reduction targets, so as to seek countermeasures to further improve the target effect of "carbon neutral".

2 Research Design

2.1 Theoretical Mechanism Analysis and Research Hypothesis

On the one hand, when the level of financial development reaches a certain extent, it will have a significant impact on the improvement of energy utilization efficiency.^[1] Financial development can also improve the availability of corporate financing and reduce corporate financing costs, thus promoting enterprises to purchase large equipment, build new production lines and expand production scale, which will inevitably increase energy consumption and carbon emissions.^[2] On the other hand, green finance policy provides preferential interest rate and loan support for green enterprises and institutions engaged in circular economy production and ecological agriculture, and implements loan amount limit and high interest rate for "three high" industries and "three low" industries. The constrained financing of highly polluting enterprises will lead to reduced capacity, lower energy consumption and carbon emissions; the increased credit funds of green enterprises will increase their production scale, providing more low-carbon technologies or producing more low-carbon products, thus reducing carbon emissions. Therefore, propose the study hypothesis:

H1. *Green finance can reduce energy consumption and carbon emissions and help achieve the "carbon neutral" goal.*

Green finance can effectively guide capital to green and low-carbon industry through the function of capital orientation, promote the development of high-tech and

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low-carbon industries, green credit control or directly refuse to provide financing loans to energy-intensive, heavy polluting and inefficient enterprises, improve corporate debt capital, thus forcing enterprises to transform and upgrade and promote the green transformation of China's industrial structure; Banks and other financial institutions support green projects, non-energy enterprises to reduce debt costs and strive to realize clean energy as the main energy raw material in enterprise production and operation, so as to realize energy consumption transformation and effectively control Chinese carbon emissions. Financial development can guide the adjustment of economic structure and energy structure and achieve low-carbon economic development by promoting enterprise technological innovation and providing financial support for environmental protection industry projects and clean production technology research and development and application, so as to achieve a sustainable reduction of carbon emissions.^[3] On the one hand, it provides policy dividends for green enterprises, alleviates the financing constraints of enterprises, and has more funds for technological innovation and research and development, thus making the "Porter effect" of environmental protection policy on the economy more significant; on the other hand, "green credit" policy forms great pressure on the survival and development of highly polluting industries, and encourages them to promote the innovation and promotion of low-carbon technologies and develop clean projects. Therefore, the following study hypotheses are proposed:

H2a. Under the goal of "carbon neutrality", industrial structure upgrading plays an intermediary role in the realization process of green finance support for energy conservation and emission reduction.

H2b. Under the "carbon neutral" goal, technological innovation plays an intermediary role in the realization of green finance in support for energy conservation and emission reduction.

2.2 Variable Selection and Data Description

2.2.1 Explained Variable

Per capita energy consumption (*AEN*). Using 11 kinds of energy consumption of coal, coke, oil, crude oil, gasoline, kerosene, diesel, fuel oil, liquefied petroleum gas, natural gas and electricity from 2009 to 2020, 11 kinds of energy consumption are uniformly converted into standard coal to calculate the total energy consumption, and then get the per capita energy consumption of all provinces and cities.

Carbon emissions per capita (*ACO₂*). The carbon emissions of provinces and cities from 2009-2020 are calculated by referring to IPCC (2006).

$$ACO_{2,it} = \frac{\sum_{j=1}^{14} E_{ij} \times NCV_j \times CC_j \times COF_j \times (44/12)}{N_{ij}}$$

Among them, *N* represents the total number; *E* represents the combustion consumption of each energy,

which are coal, coke, coke furnace gas, blast furnace gas, converter gas, other gas, crude oil, gasoline, kerosene, diesel, fuel oil, liquefied petroleum gas, natural gas and liquefied natural gas;^[4] *NCV* represents average low heat value; *CC* represents the carbon content of energy; *COF* represents carbon oxidation factor (set carbon oxidation factor of coal and coke is 0.99, other carbon oxidation factor is 1). 44/12 is the ratio of molecular weight of carbon dioxide and carbon.

2.2.2 Core Explanatory Variable

The green finance development index (*GF*). Considering that carbon finance started late and is not mature in China, and the policy support of local governments for green industry, four dimensions of green credit, green investment, green insurance and government support are selected to measure the development level of green finance (Table 1).

Table 1. Green finance development index index system.

Indicators	Indicator instructions
Green-credit	Interest expenditure of the six major energy-consuming industrial industries / total industrial interest expenditure
Green investment	Investment in environmental pollution control / GDP
Green insurance	Agricultural insurance income / gross agricultural output value
Government support	Expenditure on fiscal and environmental protection / general fiscal budget expenditure

2.2.3 Mediating Variable

Advanced industrial structure (*HIS*). The upgrading of industrial structure refers to the gradual transformation and upgrading of the secondary industry to the tertiary industry. It is a positive index expressed by the ratio of the added value of the tertiary industry to the added value of the secondary industry.

Technological innovation level (*R&D*). Considering that enterprises drive technological innovation through R&D expenditure, this paper measures the ratio of output-end R&D expenditure to regional GDP.

2.2.4 Covariables

Select the foreign trade level (*TRAD*), the three total patent applications (*PAP*), energy consumption intensity (*EN*), urbanization rate (*URB*), and economic development level (*ECD*). Specifically, the level of foreign trade is measured by the ratio of total import and export to regional GDP; the ratio of total energy consumption to regional GDP; the urbanization rate is expressed as the proportion of urban population at the end of each region; and the level of economic development is measured by per capita GDP, namely, the ratio of regional GDP to population.

2.2.5 Data Description

Due to the large lack of data in Tibet, Hong Kong, Macao and Taiwan, this paper only examines the panel

data of 30 provinces and cities in China from 2009 to 2020. Considering the possible outliers in the big data sample, the data is tailed by 2.5% to make the data smoother. All the original data are from the *National Bureau of Statistics, China Statistical Yearbook, China Energy Statistical Yearbook, China Insurance Yearbook, China Environmental Statistical Yearbook* and Wind database. Descriptive statistics for the main variables are shown in Table 2.

Fig.1 is the scatter chart of green finance and energy consumption. Fig.2 the scatter chart of green finance and carbon emissions. According to the preliminary analysis of the scatter Fig.1 and Fig.2, the development of green finance is negatively correlated with energy consumption and carbon emissions, that is, the improvement of green finance development level can reduce energy consumption and inhibit carbon emissions, and H1 has been preliminarily verified. Observe the fitting line shows that the fitting line of green finance and energy consumption is flatter than that of green finance and carbon emission. Therefore, it can be speculated that the emission reduction effect of green finance may be greater than the energy saving effect.

Table 2. Descriptive statistics of the variables.

Variable	Mean	Median	Standard	Min	Max
<i>AEN</i>	3.650	3.099	1.643	1.631	7.950
<i>ACO₂</i>	8.563	6.739	5.439	3.606	27.35
<i>GF</i>	0.175	0.150	0.0850	0.0790	0.441
<i>HIS</i>	1.486	1.242	0.979	0.0850	4.561
<i>R&D</i>	0.988	0.847	0.537	0.236	2.142
<i>EN</i>	0.809	0.624	0.509	0.220	2.160
<i>ECD</i>	5.155	4.606	2.543	1.716	12.42
<i>TRAD</i>	0.277	0.141	0.289	0.0410	1.158
<i>URB</i>	0.573	0.555	0.126	0.372	0.879
<i>PAP</i>	3.279	1.349	5.589	0.179	25.57

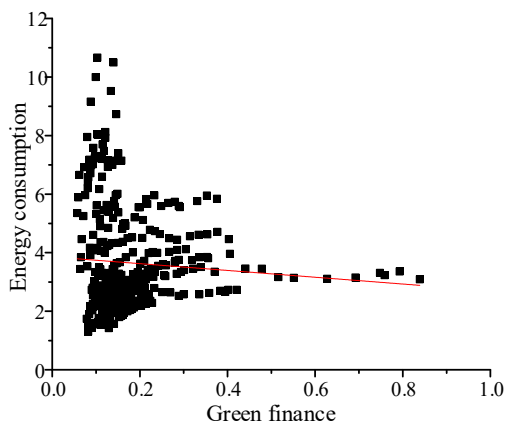


Fig. 1. Green finance and energy consumption.

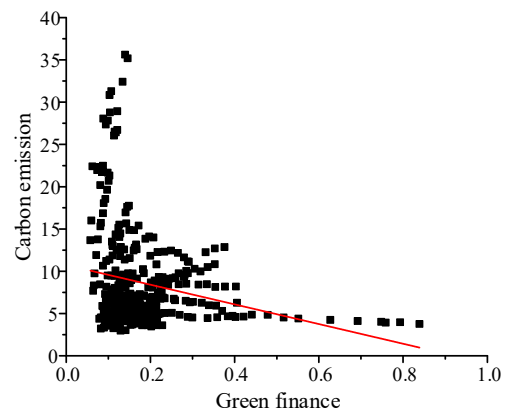


Fig. 2. Green finance and carbon emissions.

2.3 Econometric Model Setting

According to the above analysis, green finance is an important financial tool to support the realization of the "dual-carbon" goal. Under the premise of controlling other factors, the relationship between green finance and energy consumption and carbon emissions is discussed. To verify H1, the model (1).

$$Y_{it} = \alpha_0 + \alpha_1 GF_{it} + \alpha_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Y is the explained variable (per capita energy consumption AEN and per capita carbon emission ACO_2). GF is the green finance development index; X is the control variable, $\mu_i, \lambda_t, \varepsilon_{it}$ are individual fixed effect, time fixed effect and random interference items.

3 Empirical Analysis

3.1 Overall Effect Analysis

The multicollinearity test of the variables indicated that the variance inflation factor of each variable was less than 10 with a mean of 4.76, indicating that there was no severe multicollinearity among the variables. In order to improve the reliability of the model estimation results, the fixed effect model (FE) and random effect model (RE) are used to analyze the overall effect of green finance on energy consumption and carbon emission respectively. The results of Table 3 show that under both the fixed effect model and the random effect model. Firstly, the fitting coefficient between green finance and energy consumption passed the test at 1% and negative, which shows that the development of green finance can significantly reduce energy consumption in consistent with Fig.1. Secondly, the fitting coefficient between green finance and carbon emission was tested at 1%, with significant emission reduction effect in accordance with Fig.2. In turn, to test H1. Finance drives economic growth while promoting total factor productivity, thus contributing to carbon emission reduction.^[5] Thirdly, the two results show that within the above two models, the fitting coefficient of green finance to energy consumption at 1% significance level is less than that of green finance on carbon emissions, indicating that the emission reduction effect of green finance is greater than

the energy saving effect, which is in line with the inclination of the fit line in Fig.1 and Fig.2.

Table 3. Overall effect analysis.

Variable	(1)	(2)	(3)	(4)
	FE	RE	FE	RE
	<i>AEN</i>	<i>AEN</i>	<i>ACO₂</i>	<i>ACO₂</i>
<i>GF</i>	-6.966*** (1.123)	-7.536*** (1.054)	-30.657*** (3.764)	-30.496*** (3.551)
<i>EN</i>	0.569*** (0.179)	1.210*** (0.158)	2.387*** (0.601)	3.110*** (0.555)
<i>URB</i>	5.955*** (1.381)	9.087*** (1.197)	19.038*** (4.631)	26.215*** (4.181)
<i>ECD</i>	-0.019 (0.032)	0.006 (0.033)	-0.244** (0.108)	-0.165 (0.107)
<i>TRAD</i>	-0.527 (0.381)	-0.656* (0.375)	-3.701*** (1.279)	-3.782*** (1.252)
<i>PAP</i>	-0.019** (0.009)	-0.023** (0.009)	0.043 (0.029)	0.032 (0.029)
<i>Cons</i>	0.394 (0.698)	-1.876*** (0.575)	-0.163 (2.341)	-4.816** (2.100)
<i>F</i>	17.673		18.134	
<i>N</i>	360	360	360	360
<i>R²</i>	0.490	0.763	0.496	0.563
<i>Pro</i>	YES	YES	YES	YES
<i>Year</i>	YES	YES	YES	YES

Note: *, **, *** indicate significant at significance levels of 10%, 5%, and 1%, respectively.

3.2 Robustness and Endogeneity Test

In order to verify the reliability of green finance on energy conservation and emission reduction, the robustness test is carried out (Table 4). First, the foreign direct investment was increased as the control variable, and the index was also reduced by 2.5%. Second, Beijing, Shanghai, Tianjin and Chongqing were excluded for regression analysis.^[6] There may be a reverse causal relationship between green financial development and energy consumption and carbon emissions on the above empirical conclusions, so all explanatory variables lag the first order (Table 5). The robustness and regression results of the fixed effects model, the results were robust and there are no serious endogeneity problems.

Table 4. The robustness test.

Variable	(1)	(2)	(3)	(4)
	<i>AEN</i>	<i>ACO₂</i>	<i>AEN</i>	<i>ACO₂</i>
<i>GF</i>	-7.045*** (1.129)	-30.422*** (3.788)	-12.328*** (1.356)	-54.464*** (4.423)
<i>Cons</i>	0.353 (0.701)	-0.039 (2.353)	1.042 (0.705)	4.540** (2.301)
<i>F</i>	16.688	17.113	22.515	26.256
<i>N</i>	360	360	324	324
<i>R²</i>	0.491	0.497	0.578	0.615
<i>Controls</i>	YES	YES	YES	YES
<i>Year</i>	YES	YES	YES	YES
<i>Pro</i>	YES	YES	YES	YES

Table 5. Endurance test.

Variable	(1)	(2)
	<i>AEN</i>	<i>ACO₂</i>
<i>L.GF</i>	-6.379*** (1.164)	-31.851*** (3.883)
<i>Cons</i>	1.283* (0.668)	2.428 (2.229)
<i>F</i>	11.400	14.057
<i>N</i>	330.000	330.000
<i>R²</i>	0.391	0.442
<i>Controls</i>	YES	YES
<i>Year</i>	YES	YES
<i>Pro</i>	YES	YES

4 Further Analysis: Mechanism Test of Green Finance Supporting Energy Conservation and Emission Reduction

4.1 Model Design

The above, green finance can significantly support the realization of energy conservation and emission reduction targets. Can green finance achieve energy conservation and emission reduction targets through two paths: advanced industrial structure and technological innovation? Advanced industrial structure and technological innovation were selected as two intermediary variables, and the intermediary effect model was constructed by stepwise regression method.^[7]

$$Y_{it} = \varphi_0 + \varphi_1 GF_{it} + \varphi_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

$$M_{it} = \eta_0 + \eta_1 GF_{it} + \eta_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

$$Y_{it} = \gamma_0 + \gamma_1 GF_{it} + \gamma_2 M_{it} + \gamma_3 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

Among them, M represents the intermediary variable (technological innovation and industrial structure advanced). The meanings of the other variables are consistent as mentioned above.

4.2 The Intermediary Mechanism Test of Energy Consumption by Green Finance

By testing and analyzing the intermediary mechanism of green finance, energy consumption, energy conservation and emission reduction (Table 6), The following conclusions can be drawn. (1) green finance can significantly reduce energy consumption at 1%; Green finance to Advanced Industrial structure and technological Innovation fitted coefficients at the 1% level and the coefficient is positive. It shows that green finance can significantly promote the advanced industrial structure and technological innovation. (2)The coefficients of green finance and advanced industrial structure have both passed the significance test at the 1% significance level. It shows that the advanced industrial structure has some intermediary effect in the influence of

green finance on energy consumption. The guiding role of green finance is mentioned in the above article, which can guide the cash flow into the low-carbon industry, so as to improve the utilization rate of resources in the industrial capital chain, promote the transformation of more industries into the tertiary industry, and ultimately effectively reduce the energy consumption.(3) Both green finance and technological innovation are significantly negative at the 1% level, indicating that technological innovation also has a partial intermediary effect in the impact of green finance on energy consumption.

Table 6. Test of the intermediary mechanism based on energy consumption.

	(1)	(2)	(3)	(4)	(5)
Variable	<i>AEN</i>	<i>HIS</i>	<i>AEN</i>	<i>R&D</i>	<i>AEN</i>
<i>GF</i>	-6.966*** (1.123)	1.913** (0.936)	-6.620*** (1.119)	2.983*** (0.432)	-4.919*** (1.164)
<i>HIS</i>			-0.181*** (0.067)		
<i>R&D</i>					-0.687*** (0.142)
Cons	0.394 (0.698)	2.294*** (0.582)	0.810 (0.708)	-2.564*** (0.269)	-1.366* (0.766)
<i>F</i>	17.673	11.476	17.431	36.457	19.187
<i>N</i>	360	360	360	360	360
<i>R</i> ²	0.490	0.384	0.501	0.664	0.525
Control	YES	YES	YES	YES	YES
<i>Pro</i>	YES	YES	YES	YES	YES
<i>Year</i>	YES	YES	YES	YES	YES

4.3 The Intermediary Mechanism Test of Green Finance on Carbon Emission

Through testing and analyzing the intermediary mechanism of green finance, carbon emission, energy conservation and emission reduction (Table 7), The following conclusions can be drawn. (1) green finance can significantly inhibit carbon emissions at the 1% level; At 5% and 1%, respectively, green finance provides advanced industrial structure and technological innovation produces significant positive promotion; Introduce the upgrading of industrial structure as an intermediary variable into the model of green finance. The results show that the fitting coefficient of the advanced industrial structure is not significant, Immediately by the bootstrap inspection, Results showed that neither indirect nor direct effects contained 0 within the 95% confidence interval, and $\eta_1\gamma_2$ has the same number as ϕ_1 , It shows that green finance can restrain carbon emissions through advanced industrial structure, There is a partial mediation effect. Green finance effectively promotes the gradual transfer of financing from high-energy-consuming industries in the real economy to strategic high-tech industries, clean production industries and low-carbon service bank industries, and the clean and low-carbon financing trend will effectively lead the upgrading and optimization of

the industrial structure, which is an important way to achieve the goal of "emission reduction".(2) The technological innovation as an intermediary variable into the green financial model of carbon emissions, the results show that the fitting coefficient of technological innovation is also not significant, and bootstrap test $\eta_1\gamma_2$, the results show that the indirect effect and direct effect is included in the 95% confidence interval 0, shows that green financial through technological innovation to inhibit the mediation of carbon emissions is not obvious. On the one hand, green finance itself has the role of resource allocation to restrain carbon emissions; on the other hand, the emission reduction effect brought about by technological innovation in some regions is not enough to compensate for the environmental damage of incremental carbon emissions caused by economic development caused by technological innovation.

Table 7. Test of the intermediary mechanism based on carbon emissions.

	(1)	(2)	(3)	(5)	(6)
Variable	<i>ACO</i> ₂	<i>HIS</i>	<i>ACO</i> ₂	<i>R&D</i>	<i>ACO</i> ₂
<i>GF</i>	-30.657*** (3.764)	1.913** (0.936)	-30.135*** (3.786)	2.983*** (0.432)	-28.421*** (4.032)
<i>HIS</i>			-0.273 (0.227)		
<i>R&D</i>					-0.749 (0.491)
Cons	-0.163 (2.341)	2.294*** (0.582)	0.463 (2.397)	-2.564*** (0.269)	-2.084 (2.654)
<i>F</i>	18.134	11.476	17.231	36.457	17.328
<i>N</i>	360	360	360	360	360
<i>R</i> ²	0.496	0.384	0.499	0.664	0.500
Control	YES	YES	YES	YES	YES
<i>Pro</i>	YES	YES	YES	YES	YES
<i>Year</i>	YES	YES	YES	YES	YES

5 Conclusions an Policy Recommendations

Using the panel data of 30 provinces and cities in China (except Tibet) from 2009 to 2020, Performed a theoretical analysis of the empirical studies, The following conclusions are obtained. (1) green finance can reduce energy consumption and curb carbon emissions, With a good energy-saving and emission-reduction effect, And the emission-reduction effect is greater than the energy-saving effect.(2) Industrial structure upgrading and technological innovation as intermediary variables, It has partially mediated the impact of green finance on energy consumption, Help to produce an energy-saving effect.(3) Industrial structure upgrading has a partial intermediary effect in the impact of green finance on carbon emissions. To produce an emission-reduction effect. However, the intermediary role of technological innovation in the impact of green finance on carbon emissions is not significant.

Based on the above conclusions, the following recommendations.

First, Improve the development system of green finance and improve the development level of green finance. Relying on financial technology innovation technology, support the development of energy conservation and environmental protection industry by expanding the scale of green credit, vigorously develop green investment, broaden financing channels, such as attract foreign capital, diversify the investment subject, and build a unified green finance platform to support the development of green industry.

Second, Vigorously promote the upgrading of the industrial structure and promote the coordinated development of the industries. We will promote the production transformation of traditional industries such as "two remaining and one high", and accelerate the development of the tertiary industry dominated by the emerging service industry, especially in information consulting and cultural industries, so as to realize the transformation of driving drivers and sustainable economic development. At the same time, we will encourage the development of clean and low-carbon industries, reduce pollution emissions and improve energy efficiency.

Third, Accelerate the technological innovation of enterprises and guide green technology research and development. The government should actively provide financial support to enable enterprises to reduce research and development costs, broaden financing channels, promote the strengthening of green product innovation, change of production mode and production process, improve energy utilization capacity, and pay attention to the coordinated development of technological innovation and industrial structure upgrading.

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