

Research on the Impact of Green Finance on Carbon Emission

-- Mediating Effect Based on Green Technology Innovation

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Abstract: Provincial panel data from 2001-2019 are selected to construct a mediation effect model with green technology innovation as the entry point to explore the effect of green finance on carbon emissions. The study shows that: (1) the development of green finance can significantly inhibit carbon dioxide emissions, and the higher the carbon dioxide emissions, the better the inhibition effect of green financial development on carbon emissions; (2) in the eastern and central regions of China, the development of green finance have played an obvious inhibition effect on carbon dioxide emissions, and the inhibition effect on carbon emissions in the central region is stronger than that in the eastern region; (3) the level of green technology innovation There is a mediating effect in the improvement effect of green finance on carbon emissions, and the mediating effect accounts for 41.47%.

Keywords: Green finance, Carbon emissions, Green technology innovation, The mediation effect.

1. Introduction

Excessive carbon dioxide emissions are an important cause of climate anomalies and environmental degradation, and China, as the world's largest developing country, accounts for about 30 per cent of global carbon emissions, so the road to energy conservation and emission reduction in China is urgent. In his 19th National Congress report, General Secretary Xi Jinping proposed that China should "establish a sound economic system of green, low-carbon and recycling development" and "build a market-oriented green technology innovation system and develop green finance".

The concept of "green finance" first appeared in the 1970s, referring to economic activities carried out to improve the environment, combat climate change and make efficient use of resources. In the past few decades, the development of green finance in China was mainly aimed at mitigating environmental pollution, and in recent years, carbon reduction has gradually become a key goal in the development of green finance. Supporting the development of clean energy and reducing energy consumption is an important way to reduce carbon emissions, and the huge demand for capital brought about by the changing development of the industry has driven the development of green finance. On the other hand, the innovation of green technology is the key driving force to grow the development of environmental protection industry and clean energy industry, which also inhibits carbon dioxide emissions to a large extent. Therefore, based on previous research, this paper provides an in-depth study on the impact path of China's green financial development on carbon emissions, takes green technological innovation as an entry point, conducts theoretical analysis on the role mechanism of green finance affecting carbon emissions, and empirically analyses it based on the provincial panel data of 2001-2019 using the mediation effect model, to explore the green finance Based on provincial panel data from 2001 to 2019, the mediation effect model is used to carry out empirical analyses to explore the interaction mechanism between green finance, green technology

innovation and carbon emissions, with a view to providing theoretical basis for accelerating the achievement of the "double carbon" goal.

2. Literature Review and Theoretical Hypotheses

2.1. The impact of green finance development on carbon emissions

In terms of the impact of financial development on carbon emissions, most scholars believe that financial development can be used to curb carbon emissions by improving innovation through corporate finance, producing low-carbon products or by increasing energy utilisation. For example, Salahuddin(2015)[1] argues that financial development promotes corporate technological innovation and reduces carbon dioxide emissions. Shao Hanhua(2017)[2] analysed based on the panel smoothing transformation model to get that financial development in China plays a positive role in reducing carbon emissions, but this emission reduction effect presents complex heterogeneous characteristics. A part of scholars hold the opposite opinion that financial development promotes carbon emission. For example, Sadoesky(2011)[3] suggests that financial development makes consumers accelerate the consumption of energy, which exacerbates the emission of greenhouse gases. Some scholars have also argued that the relationship between carbon emissions and financial development is not purely one of facilitating and inhibiting effects, but rather one of complex impacts through mechanisms of action in different directions. Yan Chengliang(2016)[4] argues through theoretical analysis that there is an inverted U-shaped relationship between financial development and carbon dioxide concentration, and that different dimensions of financial development have different effects on carbon dioxide. Li Xuelin(2020)[5] found that the overall scale of rural finance has no significant effect on carbon emissions, but individual indicators will have different effects on the results respectively. Throughout the above

research results, the mainstream view is that financial development has a certain inhibitory effect on carbon dioxide emissions, but the relationship between the two is very complex, and the influence mechanism has not yet been concluded. In the research of green finance and carbon emissions, Xu Wenan et al.(2018)[6] selected two indicators of green investment and green insurance from 2002 to 2014, established a panel data model for empirical analysis, and obtained the conclusion that green financial development has an inhibitory effect on carbon emissions but the effect is not obvious. He Wujie et al.(2019)[7] used the VAR model to empirically analyse the green credit, green investment, green insurance and green securities data from 2001-2016, and concluded that green financial development can effectively inhibit carbon emissions, and the inhibition effect is gradually increasing. Therefore, this paper argues that under the background of "double carbon", financial institutions have begun to pay attention to the carbon emissions of enterprises, and have increased their support for corporate emission reduction. Through the introduction of green financial products, financial institutions promote the financing of green projects, support the development of environmental protection and clean energy enterprises, and encourage the green transformation of traditional industries and energy-consuming enterprises, thereby reducing carbon emissions.

Based on the above review, this paper proposes hypothesis 1:

H1: Green financial development has a significant inhibitory effect on carbon emissions.

2.2. The mediating effect of green technology innovation

In terms of the impact of green finance on green technological innovation, Calel et al.(2016)[8] found that the EU carbon emissions trading system can effectively promote the technological progress of regulated enterprises. Qu Xianchi et al.(2019)[9] based on evolutionary game theory found that green financial investment promotes enterprises' green technological innovation. He Lingyun(2019)[10] found that the scale of green credit can significantly promote the level of green technological innovation of enterprises. Wang Xu and Chu Xu(2019)[11] empirical study found that when the enterprise scale breaks through the threshold, external financing will have a significant promotion effect on green technology innovation. Green technology innovation is the key driving force for the development of environmental protection industry and clean energy industry, but compared to other production and operation activities of enterprises, the technological innovation of enterprises often requires a large amount of funds, and because of the long return on investment cycle, low returns, high risk, has been facing the problem of difficult financing, and the development of green finance will reduce the financing threshold of environmental protection enterprises, provide strong financial support for technological innovation of environmental protection enterprises, and increase the funding for green technology innovation. The development of green finance will reduce the financing threshold of environmental protection enterprises, provide strong financial support for the technological innovation of environmental protection enterprises, increase the capital investment in research and development of green technological innovation, and thus vigorously promote green technological innovation of enterprises. Therefore, the

development of green finance has gradually highlighted the role of green technological innovation.

In terms of the impact of green technological innovation on carbon emissions, He Xiaogang(2015)[12] found through empirical research that the level of green technological innovation can improve the cleanliness of the enterprise's products as well as the production efficiency with energy saving and emission reduction effects. Hu Anjun(2019)[13] showed that technological innovation can reduce pollution emissions by promoting the cleaner transformation of China's industrial structure. Liu Yuanchun(2022)[14] suggests that technological progress may also produce an energy rebound effect. Considering the drivers of emission reduction, green technology innovation is a key means to achieve carbon emission reduction. Improving the level of green technology innovation is conducive to improving the structure of energy consumption, and at the same time prompting enterprises to use resources more efficiently, reducing energy consumption and pollution emissions, thereby reducing carbon dioxide emissions.

Based on the above review, this paper proposes hypothesis 2 and hypothesis 3:

H2: Green financial development can effectively promote the progress of green technology innovation.

H3: Green financial development can effectively promote the progress of green technological innovation, and then have a significant inhibition effect on carbon emissions.

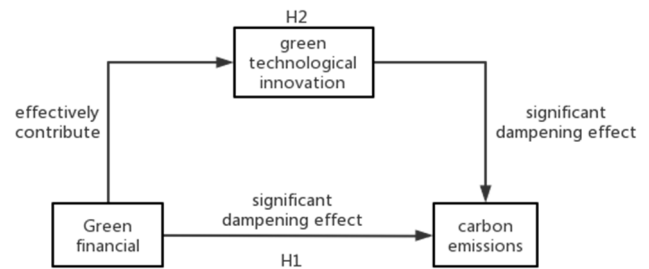


Figure 1. Research hypothesis

3. Study Design

3.1. Selection of variables and data sources

Considering a variety of factors such as data availability, the time span of the empirical analysis in this paper is 2001-2019. Due to the serious lack of data on some variables in Tibet, this paper only empirically explores the 30 provinces in China except Tibet.

(1) Explained variable: carbon emissions CO₂

The carbon emission data in this paper comes from the CEADS database, and the total apparent carbon dioxide emissions of 30 provinces from 2001-2019 are selected.

(2) Core explanatory variables: green finance development level GF

This paper examines the dynamic relationship between green finance and carbon emissions, in which the measurement of green finance development level has a certain degree of complexity, which is considered as a comprehensive indicator in this paper. Existing literature usually selects a single or a small number of indicators to measure the level of green financial development, and this paper draws on the approach of Zeng Xuewen(1995)[15] to measure the level of green financial development through four dimensions: green credit, green investment, green

insurance, and government expenditure.

Among them, in terms of government expenditure, this paper adopts the proportion of fiscal environmental protection expenditure, which reflects the government's emphasis on the development of green finance, and the data come from the China Financial Statistics Yearbook; in terms of green investment, the data on investment in the treatment of environmental pollution come from the China Environmental Statistics Yearbook of past years; in terms of green insurance, since agriculture is the industry most affected by the natural environment, this paper adopts the proportion of agricultural insurance expenditure as a proportion of total agricultural output value to approximately reflect the development of green insurance, and the data come from China Insurance Yearbook of past years; in terms of green credit, due to the lack of provincial data on the balance of energy-saving and environmentally friendly loans for the positive indicator, this paper indicates the level of green credit through the reverse of the ratio of the interest expenditure of energy-consuming industries to the total industrial expenditure, and the data come from China Industrial Statistical Yearbook. In the indicator system of this paper, the green credit data are standardised in the reverse direction, and the government expenditure, green investment and green insurance indicators are standardised in the forward direction. In response to the problem of undisclosed or missing data in some regions in the sample, this paper adopts the methods of interpolation and trend imputation to fill in the missing values.

Table 1. Measurement of indicators of the level of development of green finance

Composite Indicator	Meaning of variables	Variable Description	Indicator attributes
Level of Green Financial Development	Government expenditure	Fiscal environmental protection expenditure / Fiscal general budget expenditure	Positive
	Green Investment	Total investment in environmental pollution control/GDP	Positive
	Green Insurance	Agricultural insurance expenditure/Gross agricultural output	Positive
	Green Credit	Interest expenditure/total industrial expenditure for the six energy-intensive industries	Reverse

(3) Mediating variable: green technology innovation level GT

The data comes from CNRDS database, and the number of green inventions obtained by listed companies in 30 provinces and cities in the current year from 2001 to 2019 is manually summed up.

(4) Control variables

Considering the variables that have a greater impact on carbon emissions, the following control variables are mainly selected, and the data are all from the China Statistical

Yearbook. The meanings of the variables are shown in Table 2:

Table 2. Definitions of control variables

Name	Symbols	Variable Description
Population density	pi	Number of people at the end of the year / area of the administrative area of each locality
Foreign Direct Investment	fdi	Foreign direct investment / GDP for the year
Resident income	dpi	Disposable income of urban residents
Industrial structure	str	Secondary sector value added / GDP for the year
Gross Domestic Product	gdp	Gross Domestic Product

3.2. Model setting

3.2.1. Benchmark model construction

Based on the above analysis, this paper first constructs a baseline model of the impact of the level of green finance development on carbon emissions.

$$CO_{2ti} = \alpha_0 + aGF_{ti} + \alpha_1 Controls + \mu_{ti} \quad (1)$$

where t denotes the year and i denotes the province. α_0 , β_0 , ξ_0 denotes a constant term. Controls is a series of control variables. μ_{ti} denotes the error term. CO_2 denotes the emissions of carbon dioxide, and GF denotes the level of development of green finance.

3.2.2. Intermediary effects model construction

Based on the previous discussion, this paper draws on the intermediary effect test proposed by Wen Zhonglin et al. (2004), a mediating effects model is used to examine the direct and indirect effects of the level of green finance development on carbon emissions. This paper constructs the model.

$$GT_{ti} = \beta_0 + bGF_{ti} + \beta_1 Controls + \mu_{ti} \quad (2)$$

$$CO_{2ti} = \xi_0 + cGF_{ti} + a'GT_{ti} + \xi_1 Controls + \mu_{ti} \quad (3)$$

where t denotes the year and i denotes the province. α_0 , β_0 , ξ_0 denotes a constant term. Controls is a series of control variables. μ_{ti} denotes the error term. CO_2 denotes the emissions of carbon dioxide. GF denotes the level of development of green finance, and GT denotes green technology innovation.

4. Empirical Results and Analysis

4.1. Descriptive analysis

Table 3 shows the overall descriptive statistical results of the main variables of 30 provinces and cities in China from 2001 to 2019, and it can be seen that, except for the level of green technological innovation and gross domestic product (GDP), the standard deviation of each variable is smaller than the mean value, which indicates that there is no case of extreme values. The values related to carbon emissions indicate that there is a large gap in the level of carbon emissions in different provinces, which is related to the

population size, industrial structure and level of economic development in each region. The data on the level of green financial development indicates that there is a large gap between the levels of green financial development in different provinces, which may be due to the differences in the maturity of the financial markets in different regions, with developed regions having better investment and financing opportunities. The standard deviation of green technological innovation is 1027, with a mean much larger than the median, indicating that there are large regional differences in the level of green technological innovation among regions, and the number of green inventions is mostly concentrated in a few developed regions.

Table 3. Descriptive statistics for key variables

variable	N	mean	p50	sd	min	max
CO2	600	282.8	200.8	254.0	0.926	1700
GF	600	0.141	0.115	0.0930	0.0418	0.793
GT	600	510.5	129.5	1027	0	7126
str	600	0.460	0.435	0.268	0.0145	1.742
pi	600	440.5	287.0	636.4	7.241	3938
gdp	600	15324	10119	16625	300.1	107987
dpi	600	20453	17972	12291	5221	73849
fdi	600	0.314	0.137	0.372	0.0128	1.711

4.2. Baseline model regression analysis

Without considering the level of green technology innovation, the nonlinear relationship between green financial development and carbon emissions is first tested. According to the panel econometric model setting, this paper adopts individual fixed model, two-way fixed effect model and random effect model to test respectively, and the results are shown in Table 4. Regardless of the individual fixed effect model, two-way fixed effect model or random effect model, the estimated coefficients of the green financial development level on carbon dioxide emission are all negative, and they are all significant at 1% level, which suggests that upgrading the green financial development level can significantly inhibit carbon emissions, and hypothesis 1 is established.

Table 4. Baseline regression results for the impact of green finance on carbon emissions

	CO2		
	Individual fixed effects (1)	Double fixation (2)	Random effects (3)
GF	-1350.782*** (217.347)	-1317.840*** (250.381)	-1378.712*** (204.220)
str	93.279 (72.785)	-123.615 (75.413)	53.313 (63.928)
pi	-0.207*** (0.064)	-0.296*** (0.081)	-0.135*** (0.043)
gdp	0.004*** (0.001)	0.003*** (0.001)	0.004*** (0.001)
dpi	0.013*** (0.001)	0.011*** (0.004)	0.012*** (0.001)
fdi	80.257 (48.981)	-14.175 (52.453)	109.603*** (42.088)
_cons	181.245*** (49.067)	300.832*** (52.363)	165.822*** (52.079)
Fixed effect	+	+	-
N	600.000	600.000	600.000
r2	0.439	0.501	0.437

Note: *, ** and *** represent significant at the 10%, 5% and 1% levels, with standard errors in parentheses.

4.3. Intermediary effects test

4.3.1. Stepwise regression method

This paper refers to the mediation effect test process proposed by Wen Zhonglin et al. and uses the stepwise regression method to regress the three models one by one, and the regression results are shown in Table 5.

As shown in Table 5, the coefficient of green financial development level in model(4) is -1351, which is significant at 1% level, indicating that carbon dioxide emissions are significantly reduced with the increase of green financial development level, and hypothesis 1 is established. The estimated value of the coefficient of the level of green financial development in model(5) is 12822, which is significant at the 1% level, indicating that with the increase of the level of green financial development promotes the level of green technological innovation, and verifies hypothesis 2 of this study.

Firstly, the coefficient a, the coefficient of green financial development level in model (4), is -1351, which is significant at 1% level; then the coefficients b and a, the coefficient estimates of green financial development level in model (5) and green technological innovation level in model (6) are tested in turn, and are found to be significant, which indicates that there is a mediation effect in the model; finally, the coefficient c, the coefficient of green financial development level in model (6), is -790.1, which is significant at the level of 5%, i.e. it indicates that there is a partial mediation effect in the model, and the green financial development can indirectly affect the carbon emission through the mediation of the green technological innovation. Thus, hypothesis 3 is verified. As shown in Table 7, the total effect is -1351, the direct effect is -790.1, the mediating effect is -560.3214(12822*-0.0437), and the proportion of mediating effect is 41.47% (-560.3214/-1351).

Table 5. Results of mediating effects of green technology innovation

VARIABLES	CO2 (4)	GT (5)	CO2 (6)
GF	-1,351*** (217.3)	12,822*** (499.6)	-790.1** (323.5)
GT			-0.0437** (0.0187)
str	93.28 (72.78)	-594.5*** (167.3)	67.28 (73.34)
pi	-0.207*** (0.0643)	0.0862 (0.148)	-0.204*** (0.0641)
gdp	0.00361*** (0.000788)	0.0365*** (0.00181)	0.00521*** (0.00104)
Dpi	0.0127*** (0.00116)	-0.0446*** (0.00266)	0.0107*** (0.00143)
fdi	80.26 (48.98)	-809.6*** (112.6)	44.85 (51.08)
Constant	181.2*** (49.07)	-448.9*** (112.8)	161.6*** (49.58)
Fixed effect	+	+	+
Observations	600	600	600
R-squared	0.439	0.896	0.444
Number of pro	30	30	30

Note: *, ** and *** represent significant at the 10%, 5% and 1% levels, with standard errors in parentheses.

4.3.2. Bootstrap test

In order to make up for the shortcomings of stepwise

regression method in testing procedure, this paper uses Bootstrap method to carry out the mediation effect test, and the sample size is chosen as 5000. In the direct effect and mediation effect, the P-value is 0.000, and none of them contain 0 in the 95% confidence interval, which can be seen that there exists a part of mediation effect of green technology in the impact of green finance on carbon emission, which is consistent with the results of stepwise regression method, the results are reliable.

4.4. Heterogeneity test

4.4.1. Quantile regression test

In order to analyze whether the direct effect of green finance on carbon emissions is valid and there is heterogeneity, this paper selects quartiles 25%, 50%, 75% and 90% for the panel quantile regression, and the results are shown in Table 6. The results show that the development of green finance can significantly inhibit carbon emissions, and according to the influence coefficients of the quantile, we can see that, consistent with the results of the benchmark regression in Table 4, green finance has a significant effect on carbon emissions in all quartiles, and all of them are negative inhibition. Emissions in all quartiles, and all of them are negative, indicating that the development of green finance has a positive impact on carbon emission reduction, and the absolute value of the negative coefficient of the level of green finance development shows an increasing trend as the quantile increases. This indicates that the higher the regional CO2 emissions, the better the suppression effect of green finance on carbon emissions.

Table 6. Quantile regression results

VARIABLE	CO2			
	25%	50%	75%	90%
GF	-628.8*** (149.5)	-779.6*** (112.6)	-1,138*** (120.0)	-1,611*** (356.6)
is	-34.67*** (9.235)	-67.19*** (15.28)	-92.92*** (16.05)	23.12 (126.1)
pi	-0.0227*** (0.00750)	-0.0317*** (0.00674)	-0.0415*** (0.0113)	- (0.0226)
gdp	0.00748** (0.000482)	0.00874** (0.000837)	0.0159*** (0.00259)	0.0148** (0.00277)
dpi	0.00102 (0.000898)	0.00320** (0.00114)	0.00442** (0.00158)	0.0106* (0.00571)
fdi	57.57*** (16.51)	24.33** (10.45)	-2.544 (21.88)	-25.83 (35.11)
Constant	120.9*** (12.14)	179.0*** (10.70)	241.6*** (25.60)	299.7*** (66.60)
Observations	600	600	600	600
R-squared	0.2827	0.2788	0.2979	0.2786

Note: *, ** and *** represent significant at the 10%, 5% and 1% levels, with standard errors in parentheses.

4.4.2. Regional heterogeneity analysis

Considering the significant differences in economic development and industrial structure in different regions of China, in order to explore the regional heterogeneity of the impact effect of green financial development on carbon emissions, this paper adopts the individual fixed effect model to conduct regression analyses for the eastern, central and western regions of China respectively, and the results are shown in Table 7. The results show that in the eastern and central regions of China, green finance development has

played an obvious inhibiting effect on carbon dioxide emissions, and the inhibiting effect on carbon emissions in the central region is stronger than that in the eastern region, which may be due to the development of green finance, which fits the transformation needs of the "two-high" energy industries in the central region of China, such as Shanxi, Hunan, Hubei and other energy provinces, and produces a higher level of energy efficiency than that in the eastern region. This may be due to the fact that the development of green finance meets the transformation needs of the "two high" energy industries in the central region of China, such as Shanxi, Hunan, Hubei and other major energy provinces, and produces a stronger carbon reduction effect. In the western part of China, the impact of green finance on carbon emissions is not obvious, mainly because green finance in the western region is still in its infancy, and the innovation power of enterprises is insufficient, and their technological innovation capacity is limited, so they cannot fully meet the goal of carbon emission reduction.

Table 7. Regional heterogeneity results

VARIABLES	CO2	
	Developed regions	Less developed regions
GF	-462.4*** (147.1)	-4,856*** (772.3)
is	367.6* (194.0)	119.2 (82.88)
pi	-0.0807* (0.0430)	-0.302 (1.315)
gdp	0.00630*** (0.000541)	0.00238 (0.00206)
dpi	0.00450*** (0.00122)	0.0267*** (0.00255)
fdi	135.5*** (32.87)	203.7 (210.3)
Constant	-20.42 (101.9)	255.1 (256.3)
Observations	209	361
R-squared	0.698	0.454
Number of pro	11	19

Note: *, ** and *** represent significant at the 10%, 5% and 1% levels, with standard errors in parentheses.

4.5. Endogeneity treatment and robustness tests

4.5.1. Endogenous processing

First, The first-order lagged term of the level of green finance development is selected as an instrumental variable to assess whether green finance in the previous year affects carbon emissions in the current period. Secondly, the level of education of the population is selected as the instrumental variable in this paper, and the choice of instrumental variables should meet the requirements of exogeneity and relevance. On the one hand, the development of green finance is closely related to the cultivation and provision of green financial talents, so the level of higher education is also an important influencing factor on the development of green finance in the region; on the other hand, after controlling for the influence of other factors on carbon emissions, the level of education of residents does not show a direct link with carbon emissions, making the level of education of residents an effective instrumental variable. On the other hand, after controlling for the effects of other factors on carbon emissions, the level of education of the population does not show a direct

relationship with carbon emissions, making the level of education of the population an effective instrumental variable. According to Table 8, the sign and significance of the core explanatory variables of the regression results using two-stage squares (2SLS) are not significantly different from the OLS results, and the conclusions obtained are consistent with the previous section.

Table 8. Endogeneity test results

	CO2	
	OLS	2SLS
GF	-1378.712*** (204.220)	-1121.381*** (200.102)
is	53.313 (63.928)	-70.785** (34.506)
pi	-0.135*** (0.043)	-0.040* (0.022)
gdp	0.004*** (0.001)	0.009*** (0.001)
edu	0.012*** (0.001)	0.005*** (0.002)
fdi	109.603*** (42.088)	-9.889 (40.385)
_cons	165.822*** (52.079)	253.922*** (26.810)
Observations	600	570
R-squared	0.437	0.319

Note: *, ** and *** represent significant at the 10%, 5% and 1% levels, with standard errors in parentheses.

4.5.2. Robustness tests

To further verify the objectivity and reliability of the previous results, this paper uses the substitution of explanatory variables method to test the robustness of the model, following Guo Yiqiang et al. (2010)^[16] The accounting method re-measures the CO2 emissions and estimates the CO2 produced by three fossil fuels, namely coal, gasoline and natural gas.

$$CO_2 = \sum_{i=1}^3 (E_i * \delta_i * \varphi_i)$$

where E_i denotes the consumption of the i th energy source, and δ_i denotes the oxidation rate of the i th energy source, and φ_i denotes the emission coefficient of carbon dioxide of the i th energy source. where the CO2 emission factor is taken from the values of the National Development and Reform Commission, and the consumption of coal, gasoline and natural gas is obtained from the China Energy Statistical Yearbook. It should be noted that due to the serious data deficiency in the Energy Yearbook 2001-2003, the data from 2001-2003 were excluded from the regressions in this paper, and only the data from 2004-2020 were tested.

Table 9. Summary of energy emission factors and oxidation rates

	Coal	Petrol	Natural gas
Carbon emission factor	0.7476	0.5532	0.4435
Carbon oxidation rate	0.9	0.98	0.99

The results are shown in Table 10, which shows that after replacing the explanatory variables, the coefficient of model (7) indicating the level of green finance development is -30,922, which is significant at the 1% level, indicating that green finance significantly suppresses carbon emissions; the coefficient of green technology innovation in model (8) is still

positive, indicating that the development of green finance promotes the level of green technology innovation; the coefficient of green technology innovation in model (9) is still significant, indicating the existence of the intermediary effect, which is calculated to be 58.10%. In model (8), the coefficient of green technology innovation is still positive, indicating that the development of green finance has promoted the improvement of green technology innovation; in model (9), the coefficient of green technology innovation is still significant, indicating the existence of the intermediary effect, which is calculated to be 58.10%. In summary, the hypotheses 1, 2 and 3 of this paper still hold, proving the stability and reliability of the above empirical results.

Table 10. Robustness test results

VARIABLES	co2 (7)	GT (8)	co2 (9)
GF	-30,922*** (4,414)	13,222*** (607.2)	-17,965*** (6,297)
GT			-0.980*** (0.342)
is	5,057*** (1,453)	-482.6** (199.9)	4,584*** (1,451)
pi	-7.181*** (1.700)	0.0366 (0.234)	-7.146*** (1.687)
gdp	0.0374** (0.0160)	0.0406*** (0.00220)	0.0772*** (0.0211)
dpi	0.276*** (0.0237)	-0.0476*** (0.00326)	0.230*** (0.0286)
fdi	-1,822 (1,160)	-750.3*** (159.6)	-2,557** (1,179)
Constant	7,940*** (1,284)	-573.4*** (176.7)	7,378*** (1,289)
Fixed effect	+	+	+
Observations	480	480	480
R-squared	0.425	0.893	0.435
Number of pro	30	30	30

Note: *, ** and *** represent significant at the 10%, 5% and 1% levels, with standard errors in parentheses.

5. Conclusions and Policy Recommendations

This study takes carbon dioxide emissions in China's provinces and cities as the main research object, through theoretical analysis of green financial development on carbon emissions improvement mechanism and put forward three hypotheses, and then use the intermediary effect model to test the research hypothesis, systematically analyze the total effect, direct effect and intermediary effect of green financial development on carbon emissions, the results found that green financial development can suppress carbon dioxide emissions and The results found that green financial development can curb carbon dioxide emissions and has the mediating effect of green technological innovation. The specific findings are as follows: on the one hand, at the national level, the development of green finance can significantly suppress carbon dioxide emissions, and the higher the carbon dioxide emissions, the better the suppression effect of green finance development on carbon emissions. On the regional level, the development of green finance in both developed and less developed regions can significantly suppress carbon emissions, and the suppression effect in less developed regions is stronger than that in developed regions; on the other hand, the level of green finance development has a significant suppression effect on

carbon emissions, the level of green technology innovation has a significant promotion effect on green finance development, and the level of green technology innovation has a The intermediary effect is 41.47%.

Based on the above findings, this paper makes the following recommendations.

Vigorously promote the development of green finance.

To achieve the dual carbon goal, it is necessary to achieve the interface between the financial and carbon markets. At present, the New Crown epidemic has disrupted the economy and life, and China's economy is in a critical period of economic transformation. Deepening the development of green finance will not only help China to better play its important role in global trade, but also help China to achieve its double carbon target and green transformation of its economic structure as soon as possible. From the government's perspective, the government should play a leading role in vigorously promoting the concept of green environmental protection and introducing green finance-related support policies; for financial institutions, they should actively respond to the government's call to open up innovative green financial products and broaden the green financial market; from the perspective of enterprises, they should consciously make environmental disclosures and actively participate in green investment projects to achieve green transformation.

Increase support for green technology innovation.

The level of green technology innovation plays an important role in improving China's carbon emissions, so regions should increase their support for green technology innovation, deeply implement the concept of green innovation, and further improve the curbing effect on carbon emissions. From the perspective of the government, the government should actively play a guiding and supporting role for green technology innovation, and give preferential policies such as priority project establishment for scientific and technological projects to enterprises engaged in energy conservation and environmental protection, clean production, clean energy and other technological fields; from the perspective of financial institutions, financial institutions can actively promote market-oriented means such as emissions trading and green finance to strengthen the economic incentives for green technology innovation, and establish a perfect risk investment system to provide financial support for green technological innovation; for enterprises, they should increase their initiative in green technological innovation, implement the concept of green development and improve their green competitiveness.

Strengthen the regional exchange of green technologies.

Due to the different levels of economic development and industrial structures in different regions of China, the level of green financial development and the level of green technology innovation have different effects on carbon emissions. Therefore, China should strengthen inter-regional cooperation and exchange, synergise the development of talents, technology and capital between regions, developed regions should actively play a leading role in driving less developed regions to carry out green technology research and development, less developed regions should focus on strengthening the government's main role in green financial development and green technology innovation, expand technology exchange and collaboration with developed regions, and further give play to their own regional development advantages in accordance with The important

role of green technology innovation in the market economy to promote the comprehensive green and low-carbon transformation of economic and social development.

Acknowledgment

Foundation item: "Research on the Effect of Green Finance on Carbon Emission" (ACYC2021282), Graduate Research Innovation Fund of Anhui University of Finance and Economics.

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