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Analysis of the Influence Mechanism and Emission Reduction Pathway of Green Finance in Suppressing Carbon Intensity

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Abstract: *Green finance and green technology innovation can play a great potential in helping to achieve the "dual-carbon" target. Based on the panel data of 30 provinces in China from 2010 to 2019, the direct effect of green finance in suppressing carbon intensity is first assessed by using the benchmark regression model. The indirect effect of green technological innovation in suppressing carbon intensity is explored by using the mediated effect model, and then the regional and temporal heterogeneity of green finance and green technological innovation is assessed by grouping. Finally, the emission reduction space of each province is assessed by combining the formula of the carbon emission reduction rate of each province with the marginal emission reduction cost. The study found that: (1) green technology innovation has an indirect inhibitory effect on carbon intensity of 15.865%, and there is a significant inhibitory effect of the joint effect of green finance and green technology innovation; (2) the regional analysis reveals that there is a significant inhibitory effect of green technology innovation on carbon intensity in the east and west, and green finance promotes green technology innovation in the east. The analysis of the time period shows that with the continuous development of green finance, there is a significant increase in the direct suppression of carbon intensity by green finance and the joint suppression of carbon intensity by green technological innovation and green finance. (3) The analysis of emission reduction rate and marginal emission reduction cost shows that the higher the development index of green finance is, the smaller the space for carbon emission reduction is, the higher the cost and the more difficult it is.*

Keywords: *Green finance; Carbon emission reduction; Emission reduction efficiency; Marginal emission reduction cost*

1. Introduction

During the past decades of economic development, environmental problems such as global warming caused by excessive carbon emissions have greatly threatened human survival and growth (Jiang et al., 2020). Reducing carbon emissions to achieve sustainable development has become a global consensus. As a sizeable carbon-emitting country, China is committed to achieving carbon peak by 2030 and carbon neutrality by 2060. The Twentieth National Congress Report emphasizes "promoting green development and harmonious coexistence between human beings and nature, and actively and steadily pushing carbon peaking and carbon neutrality." However, under the context of rapid economic development, a low level of green technological innovation, a high urbanization rate, and a non-clean energy structure dominated by coal, China still has certain difficulties and challenges in achieving the dual-carbon target. Compared with the total carbon emissions and per capita carbon emissions indicators, carbon intensity can better reflect energy consumption efficiency. How to effectively reduce carbon intensity to provide a basis for the scientific formulation of emission reduction policies is of outstanding academic and practical significance.

Green finance explores the coordinated relationship between economic development and ecological protection and is indispensable in promoting energy conservation, green transformation, and carbon emission reduction. China's green financial system has continuously improved since its establishment in 2015. At present, China has initially formed a multi-level green financial products and market systems, such as green loans, green bonds, green insurance, green funds, green trusts, and carbon financial products. And market system. By the end of 2021, the balance of green loans in China was RMB 15.9 trillion, up 33% year-on-year, ranking first in the world in terms of stock size. However, it is worth noting that, due to the impact of economic level and other factors, the imbalance of regional green finance development is prominent, and green finance suppresses carbon intensity with regional heterogeneity.

Scholars have studied the role of green finance on environmental quality, energy efficiency, ecological protection, and economic development (Huang and Chen, 2022). Still, there needs to be more research on the different impact paths of green finance on carbon emission reduction. Based on this, this paper not only studies the direct effect of green finance on carbon emission reduction through a panel regression model but also explores the indirect effect of the level of green technological innovation and the interaction term between green finance and green technological innovation on carbon emission reduction through the mediation effect model, and finally applies the marginal abatement cost function proposed by William Nordhaus to measure the abatement ability and difficulty among regions. Theoretically, this paper is not limited to the study of the direct effect of green finance on carbon emission reduction but also studies the indirect impact of different intermediary variables on carbon emission reduction and the analysis of regional heterogeneity and extends the exploration path of the effects of green finance on carbon emission reduction; practically, this study investigates the effect of green finance on carbon emission reduction from a multi-dimensional approach, which can provide a better theoretical basis for the policymakers.

2. Journals Retrospection

2.1. Direct Effects of Green Finance on Carbon Intensity

Saeed Meo and Karim (2022) emphasized that green finance effectively reduces carbon emissions. Gao and Shen (2022) evaluated the green finance policy using the double difference method, and their results showed that it has a significant effect on carbon emission reduction. Jiang (2020) empirically demonstrated green finance's carbon emission reduction effect at the overall and subgroup levels. Jiang (2020) used GMM estimation and other methods to prove that green finance can inhibit carbon intensity with the Western region's best carbon emission reduction effect. First of all, green finance can promote the transition of traditional fossil energy structures to clean energy (Liu et al., 2022) to improve energy efficiency and directly reduce carbon emissions from the production side. Yang et al. (2021) pointed out that the development of green finance and the optimization and adjustment of the structure of energy and industry can significantly inhibit carbon emissions, and green finance has an essential significance in supporting the energy transition. It is of great importance in supporting energy transition. Secondly, Tian et al. (2022) used the dynamic SDM model to find that the improvement of the regional green finance development level is conducive to local carbon emission reduction and carbon removal, and Zhao et al. (2022) argued that green finance can effectively curb carbon emissions, and pointed out that the role of green finance on carbon emissions has significant regional heterogeneity. Finally, green financial resource allocation will deepen the low-carbon concept on the consumption side and promote green consumption, thus reducing carbon emissions (Li et al., 2020; Meo and Abd Karim, 2022; Paramati et al., 2021). Based on the above analyses, this paper proposes the following hypotheses.

H1: Green finance can directly suppress carbon intensity.

2.2. Green Finance, Green Technology Innovation and Carbon Intensity

Wen et al. (2022), Ren et al. (2020), Wang and Feng (2021)argued that supporting technological innovation is a crucial mechanism for green finance to achieve emission reductions, and Li et al. (2021) found that the coupling of green technological innovation-green finance-environmental regulation system of the Chinese region has a moderately high level of coordinated development. Both green technological innovation and green finance have a positive effect on ecological development. Yao and Xu (2023) found that the green credit policy can significantly enhance the level of green technology innovation of enterprises and especially promote their green technology innovation activities in some low-carbon pilot cities.

The allocation function of green financial resources mainly affects the structure of green technological innovation through three aspects: (1)the government's green policy effectively guides the flow of funds to the green industry, causing changes in the number, scale and quality of green enterprises; (2) enterprises increase the strength of independent research and development, external procurement and practical application of green technology, leading to the enhancement of the speed of research and development of green patents and the number of applications; (3) the colleges and universities make use of financial allocations to carry out professional reform, causing changes in the structure of green talents

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(Wakeford et al., 2017; Song et al., 2020).

Green technological innovation requires a large amount of capital investment. It needs to solve the financing problem with the help of external financial markets, which is made possible by the applicability and profitability of green technology. Green finance's capital aggregation and function transform scarce resources into a form of capital that can be registered and traded with value and return. The market uses green financial products such as green credit, green securities, and green insurance to promote the capitalization of green technology and transform practical and scarce green technology into capital with profitability in the future. The government, financial institutions, private and other multi-channel financing methods not only can improve the efficiency of enterprise green science and technology project financing but also can reduce the cost of enterprise financing, optimize the asset structure, and expand the scale of green technology innovation (Zhao et al., 2022).

Green technology innovation is characterized by high uncertainty, long cycles, and significant R&D investment. These characteristics require financial institutions to develop and enrich financial products adapted to the needs of the green technology market, which can break the boundaries of green technology innovation and extend green financial services. The green financial information disclosure mechanism is conducive to capital market risk avoidance, screening of high-quality projects, and reducing the information search cost of financial institutions. Green technology enters the asset pool, disperses and hedges risks through asset securitization, saves innovation costs, and improves capital efficiency.

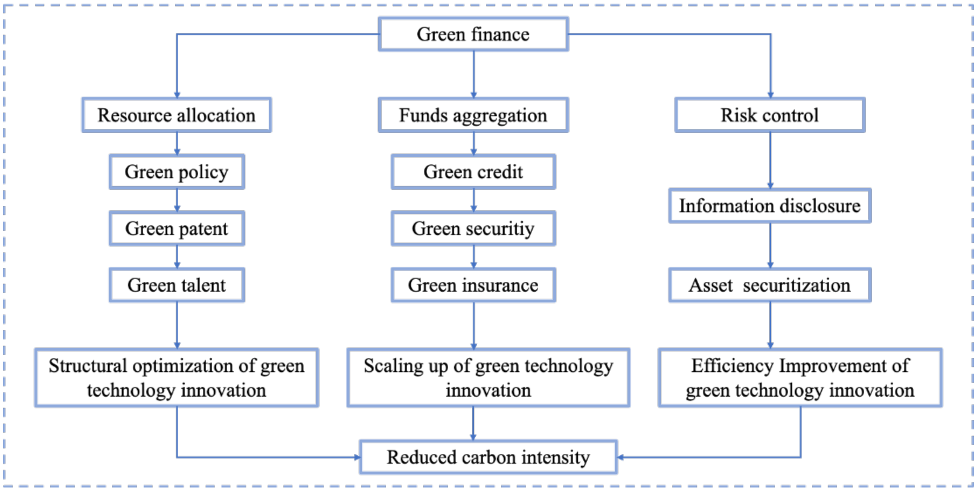

Figure 1: The map of green finance enhancing green technology innovation to achieve carbon emission reduction

Based on the above analysis, the following two hypotheses are proposed.

H2: Green finance can promote green technology innovation and thus indirectly reduce carbon intensity.

H3: The inhibitory effect of green finance on carbon intensity increases with green technology innovation.

3. Research Design

3.1 Variable Selection

3.1.1 Explained Variable

Carbon intensity (CEI): carbon emissions per unit of GDP, the ratio of total carbon emissions to real GDP.

$$CEI=\frac{CO_2}{GDP} \tag{1}$$

3.1.2 Explanatory Variable

The core explanatory variable of this paper is the Green Financial Development Index (GFI). Because

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a single indicator, such as green credit, green investment can not fully and accurately reflect the green financial development index, given the choice of different scholars' measurement indicators, such as Lee and Lee (2022), this paper adopts the entropy method to measure the green financial development index. The categories of the measurements include green credit, green investment, green insurance, green bonds, green expenditure, green funds, green rights and interests, and the green financial development index ranges between 0 and 1. The specific categories are shown in Table 1.

Table 1: GFI measurement categories and their indicators

Categories	Indicators
green credit	total credit for environmental projects/total credit for the province
green investment	investment in environmental pollution control/GDP
green insurance	environmental pollution liability insurance income/total premium income
green bonds	total green bond issuance/total all bond issuance
green expenditure	financial environmental protection expenditures/financial general budget expenditures
green funds	total market capitalization of green funds/total market capitalization of all funds
green rights and interests	carbon trading, energy rights trading, emissions trading/total equity market transactions

3.1.3 Intermediate Variables

Based on the proposal of Wen et al. (2022) that green finance should be realized to promote technological innovation and help achieve the dual-carbon goal, this paper takes the level of green technological innovation (GP) and the interaction term between green finance and green technological innovation (GFI*GP) as the mediator variables to explore the indirect effect of green technological innovation on the suppression of carbon intensity. This paper takes the number of green patents granted in each province as a proxy variable for the level of green technological innovation in each province.

3.1.4 Control Variables

Referring to the existing literature, the main control variables in this paper are the level of economic development (GDP), population density (PD), consumer price index (CPI), and urbanization rate (UR, urban population/total population).

3.2 Model Building

3.2.1 Panel Regression Model

The following panel regression model was developed to test the effect of GFI on CEI:

$$lnCEI_{it}=\alpha_0+\alpha lnGF_{it}+\sum\beta_j Control_{jit} \tag{2}$$

Where $\ln CEI_{it}$ represents the carbon dioxide emission intensity of province i in year t, $\ln GF_{it}$ represents the green financial development index of province i in year t, and $Control_{jit}$ represents the control variables.

3.2.2 Mediated Effects Model

In this paper, we use the mediation effect model to study the indirect effect of green technology innovation on carbon intensity, and X, Y, and M are the core explanatory variable, the explanatory variable, and the mediating variables, respectively. The three-step regression equation of the mediated effect model is shown in (3)-(5). Firstly, the coefficient c in equation (3) must be significant to continue the model regression. Secondly, test the coefficient a in (4) and the coefficient b in (5) significance, when the coefficient a and the coefficient b are significant, the mediation effect exists; when the coefficient a and the coefficient b at least one is not significant, Bootstrap test should be conducted to test if the confidence interval contains 0. Finally, test the coefficient c' in (5); if c' is significant, then it is a partially mediated effect; if c' is not significant, then it is a fully mediated effect.

$$Y=cX+\varepsilon_1 \tag{3}$$

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$$M = aX + \varepsilon_2 \tag{4}$$

$$Y = c'X + bM + \varepsilon_3 \tag{5}$$

3.3 Data Sources and Descriptive Statistics

Due to the lack of data related to Hong Kong, Macao and Taiwan, the data scope of this paper is only related to 30 provinces, autonomous regions and municipalities in China from 2010 to 2019, which are mainly obtained from the National Bureau of Statistics, the Cathay Pacific CSMAR database, the CEIC database, the China Energy Statistical Yearbook and the China Financial Yearbook. The descriptive statistics of the main variables are shown in Table 2.

Table 2: Descriptive statistics

Variables	N	Mean	SD	Min	Max
ln*CEI*	300	0.655	0.648	-1.121	2.115
ln*GFI*	300	-0.325	0.090	-0.509	-0.154
ln*GP*	300	9.988	0.527	8.442	10.772
ln*GDP*	300	9.694	0.893	7.042	11.59
ln*PD*	300	5.458	1.278	2.053	8.257
ln*CPI*	300	4.631	0.012	4.611	4.666
ln*UR*	300	-0.572	0.21	-1.085	-0.11

In Figure 2, lighter colours represent lower indices, darker colours represent higher indices, and data for Hong Kong, Macao, and Taiwan are missing. In 2010, the green financial development index was higher in the eastern region, and in 2018, it was higher in the east-central region. With economic development and the passage of time, the green financial development index of all provinces shows a rising trend year by year, which is more conducive to ecological protection and sustainable development.

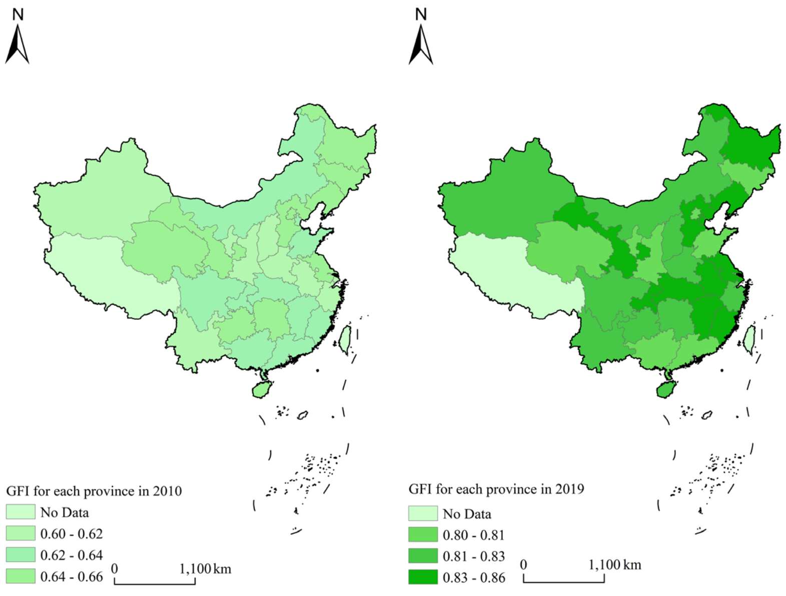

Figure 2: Green finance development index by province in 2010 and 2019

4. Empirical Results

4.1 Direct Effects Analysis

As shown in Table 3, the coefficient of ln*GFI* on ln*CEI* is -1.009, which is significant at the 5% level, and each 1% increase in GFI reduces CEI by 1.009%. Since the main regression does not take into account the mediator variable (ln*GP*), GFI has a direct inhibitory effect on CEI, and H1 is thus confirmed. Among the control variables, the coefficients of ln*GDP*, ln*PD*, and ln*UR* on ln*CEI* are -0.227 significant

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at 1% level, -0.165 significant at 1% level, and -0.432 significant at 5% level, respectively. The main regression result of the explanatory variables is significantly negative on the explained variables and the mediation effect model can be continued.

Table 3: Results of main and mediation regressions

	(1)	(2)	(3)	(4)	(5)
Variables	ln*CEI*	ln*GP*	ln*CEI*	ln*GFI**ln*GP*	ln*CEI*
ln*GFI*	-1.009** (0.399)	0.580* (0.314)	-0.848** (0.393)	9.861*** (0.108)	-6.811*** (2.132)
ln*GP*			-0.276*** (0.073)		
ln*GFI**ln*GP*					0.588*** (0.212)
ln*GDP*	-0.227*** (0.042)	0.123*** (0.033)	-0.193*** (0.042)	-0.040*** (0.011)	-0.203*** (0.042)
ln*PD*	-0.165*** (0.032)	0.230*** (0.025)	-0.102*** (0.036)	-0.0717*** (0.009)	-0.123*** (0.035)
ln*CPI*	-1.497 (2.787)	0.508 (2.193)	-1.357 (2.726)	0.648 (0.757)	-1.879 (2.760)
ln*UR*	-0.432** (0.167)	-0.0229 (0.131)	-0.438*** (0.163)	-0.0151 (0.0453)	-0.423** (0.165)
Constant	10.11 (12.89)	5.367 (10.140)	11.600 (12.610)	-2.264 (3.499)	11.450 (12.760)
Observations	300	300	300	300	300
R-squared	0.470	0.504	0.495	0.980	0.484

Note: ***, **, * indicate significant at the 1%, 5 % and 10 %, respectively, with standard errors in parentheses, as below.

4.2 Intermediation Effects Analysis

Mediated effects models are used to investigate the transmission mechanisms through which explanatory variables can affect the explained variables, also known as mechanism analysis. Column (2) in Table 3 presents the effect of GFI on GP, with a coefficient of 0.58 significant at the 10% level, and column (3) indicates that after the introduction of the mediating variable ln*GP*, ln*GFI* and ln*GP* affect ln*CEI*, and the coefficient of the effect of ln*GFI* on ln*CEI* changes from -1.009 to -0.848, which is significant at the 5% level, and the inhibitory effect of GFI on CEI is weakened by 0.161%. This weakening is partially transmitted through the mediating mechanism, the indirect effect of ln*GP* on ln*CEI* is -0.16 (-0.580*0.276), H2 is thus proved. The significant negative coefficient of ln*GP* on ln*CEI* also indicates that this is a partially mediated effect transmission mechanism. The regression results of the interaction term ln*GFI**ln*GP* are shown in columns (4)-(5) of Table 3, and the coefficient of ln*GFI**ln*GP* in column (5) is 0.588, which is significant at the 1% level, suggesting that GP enhances the inhibitory effect of GFI on CEI, which confirms H3.

The above regression results use causal stepwise regression results, which may have the problem of the correctness of the procedure test. In order to solve this aspect of the problem and make the regression results more scientific and accurate, this paper adopts the Bootstrap method commonly used by scholars such as Zhang et al., 2016, Fang et al., 2013 and Chen et al., 2013 in recent years to carry out the mediation effect test. The test results are shown in Table 4.

Table 4: Bootstrap test results

Variables	effects	coefficient	SD	Z value	P value	95% confidence interval(bc)	
ln*GP*	_bs_1	-0.160	0.092	-1.74	0.083	-0.398	-0.025
	_bs_2	-0.848	0.384	-2.21	0.027	-1.575	-0.045
ln*GFI**ln*GP*	_bs_1	5.802	1.741	3.33	0.001	2.362	9.234
	_bs_2	-6.811	1.708	-3.99	0.000	-10.321	-3.522

_bs_1 represents the indirect effect, or the mediating effect, and _bs_2 represents the direct effect. From the above table, it can be seen that in the process of the impact of green finance on carbon emission reduction, the direct effect and indirect effect are both significant, the 95% confidence interval does not contain 0, but there is a mediating effect. Table 3 stepwise regression results are credible. It can be seen that there is a significant mediating effect of green technology innovation level on carbon emission

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reduction in the impact of green finance on carbon emission reduction, and H2 is also valid. At the same time, the regression coefficients *c*, *a*, *b* and *c'* of the mediation effect model can be calculated by causal stepwise regression test to find out the size of the mediation effect. The size of the direct effect and the mediation effect proportion are shown in Table 5.

Table 5: lnGP, lnGFI lnGP effect shares*

Variable	Original coefficients			Variable	Original coefficients		
	c	*a*	*b*		*c*	*a*	*b*
ln*GP*	-1.009	0.580	-0.276	ln*GP**ln*GFI*	-1.009	9.861	0.588
Results	Direct effect	*c'*	-0.848	Results	Direct effect	*c'*	-6.811
	Mediated effect	*a*b*	-0.160		Mediated effect	*a*b*	5.7982
	Mediated effect /total effect	*ab/c*	15.865%		Mediated effect /total effect	|*ab/c*|	5.746

The mediating effect of GP on CEI accounted for 15.865% of the total effect of GFI on CEI. In the process of the inhibitory effect of GFI on CEI, 15.865% of the inhibitory effect of GFI on CEI was that GFI inhibited CEI by promoting GP. The continuous development of GFI had a stronger promotional effect on GP, and the joint inhibitory effect of GFI and GP on CEI was more significant, and every 1% increase of GFI made the interaction of GP and GFI increase by 9.861%. And the interaction between GP and GFI not only directly inhibits 6.811% CEI, but also enhances the inhibitory effect of GP on CEI by 0.588%.

4.3 Heterogeneity Analysis

Table 6 shows the results of the regression on regional heterogeneity. In the effect of green financial development to promote the level of green technological innovation, the eastern region is significantly positive, indicating that green finance to promote the level of green technological innovation to improve the various links are opened up and truly effective in promoting the transformation and application of green technological achievements. In contrast, the central region and the northeastern coefficients are significantly negative, indicating that the green financial negative impact on green technological innovation. The reasons for this may be: firstly, to confirm whether the funds raised by finance are effectively invested in green technology innovation and not used for other purposes such as subsidizing the cost of production factors; secondly, whether the relevant intellectual property rights protection and incentive policies are in place to ensure that the research and development results of green technology innovators are achieved; and thirdly, due to the long cycle of green technology innovation and the high risks involved, the funds used for green technology innovation not only fail to return to the capital but also lose a considerable opportunity cost without reasonably controlling the risks and meeting the principle of maximizing the use of the resources.

Table 6: Regression results for the East, Central, West, and North-East regions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	East	Middle	West	Northeast	East	Middle	West	Northeast
Variables	ln*CEI*	ln*CEI*	ln*CEI*	ln*CEI*	ln*GP*	ln*GP*	ln*GP*	ln*GP*
ln*GFI*					0.525*	-1.485***	1.184	-1.347***
					(0.290)	(0.344)	(0.771)	(0.266)
ln*GP*	-0.662***	-0.374	-0.224**	0.340				
	(0.100)	(0.613)	(0.093)	(0.471)				
ln*GDP*	-0.065***	-1.372**	-0.334***	1.059**	0.131***	0.843***	0.084	0.160
	(0.025)	(0.638)	(0.078)	(0.392)	(0.026)	(0.074)	(0.070)	(0.186)
ln*PD*	0.537***	1.213	-0.108*	-0.022	0.030	-0.940***	0.313***	-0.406***
	(0.047)	(0.735)	(0.063)	(0.221)	(0.056)	(0.121)	(0.047)	(0.036)
ln*CPI*	3.709	-50.370*	-31.180***	-0.272	1.695	0.535	-0.823	0.683
	(5.989)	(26.867)	(10.889)	(8.299)	(2.311)	(1.509)	(4.723)	(1.387)
ln*UR*	-3.510***	3.559***	0.186	-3.026	0.094	-0.005	-0.669**	3.729***
	(0.216)	(1.024)	(0.329)	(3.137)	(0.217)	(0.343)	(0.337)	(0.846)
Constant	-14.328	247.071*	151.624***	-12.193	1.174	4.022	11.226	8.903
	(27.446)	(125.242)	(50.570)	(38.761)	(10.707)	(6.970)	(21.810)	(6.942)
Observations	100	60	110	30	100	60	110	30
R-squared	0.871	0.653	0.521	0.854	0.319	0.771	0.469	0.921
Year FE	YES	YES	YES	YES	YES	YES	YES	YES

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In terms of the effect of green technological innovation on suppressing carbon intensity, it is significantly negative in the eastern and western regions, and not significant in the central and northeastern regions.

Table 7 shows the results of the time period heterogeneity regression. The green financial development index of each province is generally an increasing trend year by year, and this paper regresses the sample interval in time periods. The results show that the inhibitory effect of GFI on CEI is enhanced from -5.999 to -8.427, and the coefficient of the interaction term ln*GFI**ln*GP* also rises from 0.582 to 0.961, which suggests that with the development of GFI, the joint and inhibitory effect of GFI and GP on CEI increasing. H3 also holds true. The significance of the two time periods has decreased, which can be further explained according to the law of diminishing marginal utility. In the initial years, the inhibitory utility of GFI on CEI is definitely the strongest, and as GFI keeps increasing, its inhibitory utility decreases, in an inverted U-shaped relationship.

*Table 7: lnGFI and lnGFI*lnGP impact on lnCE in 2010-2014 and 2015-2019*

	2010-2014	2015-2019
Variables	ln*CEI*	ln*CEI*
ln*GFI*	-5.999***(2.211)	-8.427*(4.765)
ln*GFI**ln*GP*	0.582***(0.222)	0.961**(0.456)
ln*GDP*	-0.169***(0.051)	-0.220***(0.067)
ln*PD*	-0.0735*(0.044)	-0.137**(0.056)
ln*CPI*	1.345(3.263)	-21.280**(8.743)
ln*UR*	-0.561***(0.176)	-0.173(0.309)
Constant	-3.871(15.100)	102.000**(40.600)
Observations	150	150
R-squared	0.502	0.462

4.4 Emission Reduction Efficiency and Marginal Abatement Costs

For the calculation of marginal abatement cost, most scholars use the directional distance function, such as Cao et al. (2022) using the quadratic DDF function to derive that the marginal abatement cost in the east and central regions has a U-shaped relationship with carbon intensity, and the western region has an inverted U-shape relationship; Ru et al. (2022) based on the three directional distance function researching that the marginal abatement costs all show the trend of rising, then falling, and then rising; Wei et al. (2023) using the non-parametric estimation method of the directional distance function to point out that most of the industrial industries can achieve carbon peak on schedule in 2030, and some heavy industrial industries need to accelerate the transformation speed. This paper draws on the carbon emission reduction rate calculation method in Shen (2011) and the formula for carbon emission reduction rate per unit of GDP is as follows:

$$R_t=1-\frac{D_t}{D_{t-1}} \tag{6}$$

Where R_t is the carbon emission reduction rate per unit of GDP in year t relative to year $t-1$, D_t is the carbon emission per unit of GDP in year t, and D_{t-1} is the carbon emission per unit of GDP in year $t-1$, and in this paper, $D_t=CEI_t$. Combined with the marginal abatement cost function put forward by Nobel Prize-winning economist William Nordhaus, we take Jiangsu Province of Yangtze River Delta as an example to study the potential relationship between the change of marginal abatement cost in the past years and the Green Financial Development Index (GFI). The marginal emission reduction cost function is as follows:

$$MC=\alpha+\beta ln(1-R) \tag{7}$$

$$MC=\alpha+\beta ln\frac{CEI_t}{CEI_{t-1}} \tag{8}$$

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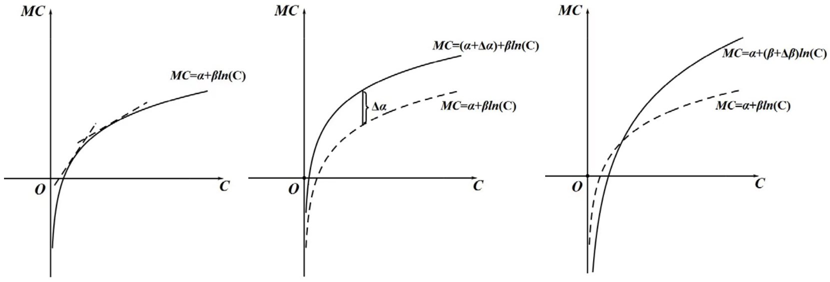

Figure 3: Marginal abatement cost function

In the formula (8), CEI_t/CEI_{t-1}, α and β are all greater than 0. From the three function diagrams in Figure 3, we can see that the marginal abatement cost (MC) decreases with the decrease of carbon intensity CEI, and increases with the increase of CEI. The two are directly proportional to each other. When the tangent slope of the curve changes from large to small (the first function graph), the corresponding change in C when MC changes will be more, meaning that the flatter the tangent slope, the greater the range of changes in the independent variable accepted by the dependent variable; when the fixed abatement cost α increases (the second function graph), the curve is shifted upwards; when the abatement cost coefficient β increases, the MC increases at an exponential level (the third function graph).

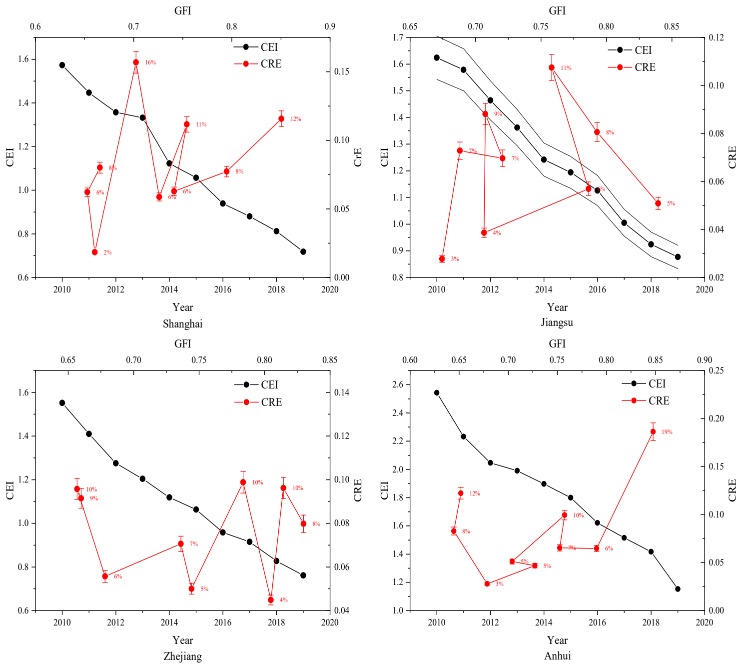

Figure 4: Yangtze River Delta Region Trends in Indicators

Figure 4 plots the double X and double Y axes, taking the Yangtze River Delta region as an example. With the continuous development of the economy and the implementation of the corresponding green policies, the carbon intensity of each province mostly shows a decreasing trend year by year, taking Jiangsu Province in Figure 4 as an example, the carbon intensity has an obvious decreasing trend, while the carbon emission reduction rate shows an inverted U-shaped curve (Cao et al., 2022), and the carbon emission reduction rate reaches the highest (9%) when the green financial index develops to a certain degree (0.71). When the green financial index continues to rise, the carbon emission reduction rate shows a downward trend, indicating that the higher the level of economic development and the higher the degree of green financial development of the provinces, the lower the carbon emission reduction rate, the greater the difficulty of carbon emission reduction, and the greater the cost of carbon emission reduction.

5. Conclusions And Policy Implications

This paper selects the panel data of 30 provinces in China from 2010 to 2019 and uses the mediation effect model to assess the inhibitory effect of green finance on carbon intensity. The main regression results show that green finance can significantly reduce carbon intensity; the mediation effect regression results show that the partial inhibition effect of green technological innovation on carbon intensity exists significantly, and there is also a significant inhibition effect of the joint effect of green finance and green technological innovation, and with the increase of the green finance development index, the joint and inhibition effect of the two is also strengthened. Although the coefficients and significance are in line with the theoretical expectations, but in order to make the results more scientific, this paper also applies the Boostrap test to further verify the existence of intermediary effects (confidence interval does not contain 0); the heterogeneity analysis concludes that there is a regional difference in the inhibition of green technology innovation on carbon intensity, of which there are significant inhibition of the East and the West, while in the analysis of the green financial promotion of green technological innovation, the East is significantly positive. The analysis of time period shows that with the continuous development of green finance, the direct inhibition of carbon intensity by green finance and the joint inhibition of carbon intensity by green technological innovation and green finance have all been significantly improved; through the analysis of carbon emission reduction rate and marginal emission reduction cost, it is concluded that (taking Jiangsu as an example), the higher the green finance development index is, the smaller the space for carbon emission reduction is, the higher the cost is, and the more difficult it is, and the lower the green finance development index is, the larger the space for carbon emission reduction is, the lower the cost is, and the easier it is.

The findings of this paper provide the following policy insights for realizing the goal of dual-carbon target under the new development concept and helping green finance to promote green technological innovation to achieve carbon emission reduction: (1) Actively expand the coverage of green finance. Vigorously develop green financial products, enhance financial services, vigorously develop green financial institutions, and improve the green financial system; formulate corresponding policies and systems, strengthen regional international cooperation in green finance, realize the interconnection between the East, the Middle East, and the West, and take the East as a leader to drive other regions to jointly realize the strategy of carbon emission reduction. Deepen the development of green finance, mobilize and encourage social capital to actively participate in green finance so that funds can flow into the green industry. Give full play to the capital aggregation functions of green securities, green credit, green insurance, and carbon financing. (2) Allocate resources to support the development of high-tech green products. Provinces and municipalities should give full play to the role of the national industrial fund in the promotion and implementation of talent introduction policies, improve the national talent service system, lower the threshold for settlement, and attract outstanding talents. Enterprises are encouraged to actively promote the construction of a system for sharing the proceeds of innovation to stimulate the enthusiasm of scientific and technological researchers and developers. At the same time, it is necessary to improve property rights protection laws and intellectual property protection. The state should clarify the meaning of "green patents" as early as possible, define the scope of patented technologies, and formulate a list of "green technology" patent categories. Construct patent-related databases to ensure information disclosure, sharing, and interconnection. (3) Provide financial support for the linked development of green finance and green technology innovation. The government should formulate a long-term mechanism to stimulate innovation in the field of green technology, establish effective compensation protection measures, and provide appropriate financial support; financial institutions should innovate green financial products to alleviate the financing constraints on small and medium-sized enterprises (SMEs), and use investment and financing leverage to promote green technological innovation, in order to enhance the benefits of SMEs' innovation. (4) Encourage technological innovation. Under the background of the national dual-carbon target policy, the governments of provinces and municipalities should formulate corresponding policies in accordance with their own realities to help the development of the science and technology industry and green finance. Use good policies to break the barriers to the application of new technologies, encourage investment in green technological innovation, and effectively improve the green environmental benefits brought about by green technological innovation. Let the green industry have more resources to create conditions for solving the necklace and other technical problems. Put technological innovation in a decisive position, stimulate the vitality of enterprise innovation, and encourage enterprises to develop new energy. Local governments and enterprises should fully develop green finance to promote the level of green technological innovation and at the same time promote the development of green finance based on scientific and technological innovation, forming a model of mutual benefit.

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