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Research on the Impact of Green Finance on Carbon Emission Efficiency—Focusing on the Threshold Role of Green Technology Innovation

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Abstract: Green finance facilitates the attainment of low-carbon economic progression by steering the allocation of capital, aiding in the achievement of the "double carbon" objective. Utilizing panel data from 30 provinces, municipalities, and autonomous regions across China spanning from 2005 to 2021, this study empirically examines the influence of green finance on carbon emission efficacy through a two-way fixed effects model, while investigating the role of green technological innovation in this dynamic by integrating the threshold effects model. The findings indicate that (1) green finance markedly enhances carbon emission efficacy. (2) There exists a singular threshold for green technological innovation. As the level of green finance escalates, the improvement in carbon emission efficacy exhibits a pattern of augmentation, diminishment, and subsequent re-augmentation. (3) An analysis of regional heterogeneity reveals that green finance in the eastern region significantly fosters carbon emission efficacy, whereas an inhibitory effect is observed in the central and western regions. Consequently, it is imperative to refine the green financial framework, advance green technological innovation, and implement tailored financial strategies commensurate with regional requirements to facilitate the realization of the "double carbon" aim.

1. Introduction

To address the challenges posed by global climate change and escalating environmental degradation, China has undertaken various initiatives, notably proposing in 2020 the ambitious targets of achieving "carbon peaking" by 2030 and "carbon neutrality" by 2060. Following this, the 20th Party Congress report emphasized the need to hasten the green transformation and actively and prudently advance towards carbon peak and carbon neutrality, underscoring the significance of realizing the "dual carbon" objective. In 2021, the State Council articulated in its Opinions on the Comprehensive and Accurate Implementation of the New Development Concept concerning Carbon Peak and Carbon Neutrality the necessity to proactively cultivate green finance and systematically promote the development of green and low-carbon financial products and services, thereby clearly delineating the supportive role of green finance in achieving the "dual carbon" goal.

In 2022, China's carbon emissions soared to 11.477 billion tons, a substantial increase from 7.71 billion tons in 2009, reflecting a rise of approximately 49%. As the largest emitter of carbon globally,

the urgency for carbon emission reduction is evident. Green finance constitutes an economic endeavor aimed at fostering ecological enhancement, responding to atmospheric alteration, and ensuring the optimal deployment of resources, thereby facilitating sustainable economic growth through the tactical distribution of social and economic resources. In this milieu, exploring the influence of green finance on carbon emission efficacy, investigating its transmission mechanisms, and aiding in the attainment of the "double carbon" objective holds significant practical importance.

Studies on green finance primarily emphasize its measurement and the impact it produces. Most scholars measure the level of green finance development by constructing an indicator system, and most scholars construct the indicator system from the level of green credit, sustainable investments, green financial assets, green insurance and so on (Zhang Ting et al., 2022; Yu Bo et al., 2022)[1-2] . However, the weights of the indicators are different, Yu Bo et al. (2022)[2] use entropy value method to measure, and Hu Wentao et al. (2023)[3] use principal component analysis method to measure. There are also scholars who use a single indicator to measure, Xiao Xiaojun et al. (2023)[4] believe that green credit is the main green financial product, so green credit is used to indicate the level of green financial development. Numerous scholars have explored the benefits brought by the growth of eco-friendly finance from different perspectives, mainly focusing on the following three aspects. At the macro level, Lin Muxi et al. (2023)[5] found that green finance promotes high-quality economic advancement; at the industry level, Chai Zhengmeng et al. (2024)[6] found that green finance aids in fortifying the robustness of the manufacturing industry and strengthens the ability to withstand environmental and industry risks; at the micro level, Wu Yonggang et al. (2024)[7] found that carrying out green finance business reduces the level of risk taking by commercial banks.

Research on carbon emission efficiency predominantly emphasizes its quantification and the factors influencing it. Most scholars typically employ input-output efficiency estimation methodologies, with one approach examining a singular factor, quantified as CO2 emissions per unit of GDP; the other adopts a multifactor perspective, which holistically considers diverse production inputs, including labor and capital, and is assessed through data envelopment analysis. Numerous determinants can influence carbon emission efficiency, such as economic progression, environmental governance, and urbanization. Huijuan et al. (2021)[8] discovered that an escalation in economic advancement can bolster carbon emission efficiency, while Ma Hailiang et al. (2020)[9] found that varying types of environmental regulation exert distinct effects on carbon emission efficacy differently across regions, noting that market incentive-based regulations initially lead to a decline in carbon emission efficiency with heightened regulatory intensity. Additionally, Wang Xinjing et al. (2020)[10] identified a detrimental influence of urbanization on the enhancement of carbon emission productivity.

Regarding the effect of eco-friendly finance on carbon output efficiency, at the micro level, green finance facilitates enterprises' green technological innovation and fosters ecological transformation by supplying capital, thereby enhancing carbon emission efficiency (Xin Wang et al., 2021)[11]. At the industrial level, green finance constrains the funding of heavily polluting sectors by limiting capital investment, thus advancing carbon emission efficiency (Su Dongwei et al., 2018)[12]. At the macro level, sustainable finance exhibits a notable and robust influence on improving carbon emission efficiency in China, with the most pronounced effects observed in the eastern region (Wu Honghan et al., 2023)[13]. Green finance mitigates the risks associated with green technological innovation, satisfies the financial requirements of entities engaged in such innovation, and optimizes resource allocation, thereby promoting green technological innovation (Xiao Renqiao, 2023)[14]. Furthermore, inventive and enhanced green technological advancement fosters the augmentation of carbon emission efficacy (Yang Haochang, 2023)[15].

A review of the literature reveals that existing studies predominantly concentrate on the influence of green finance on carbon emission efficiency, with scant attention given to green technological

innovation as a threshold variable within the research framework. Hence, this paper integrates green technological innovation to explore the effect of green finance on carbon emission efficacy, considering its threshold role.

Consequently, this research harnesses panel data from 30 provinces and municipalities in China, covering the period from 2005 to 2021. The study investigates the influence of green finance on carbon emission efficiency, delves into the mediating function of green technological advancement within this dynamic, and conducts a thorough analysis of the regional variances in this effect.

2. Impact mechanisms and research hypotheses

Green financial instruments encompass mechanisms such as green credit, green investment, green bonds, and green insurance, all of which facilitate the alignment of economic expansion with ecological conservation by furnishing financial backing for the advancement of low-carbon and environmentally-friendly technologies and initiatives. From a capital flow standpoint, green finance catalyzes the reallocation of funds from industries characterized by high pollution and energy consumption to those focused on resource efficiency and environmental preservation, thereby enhancing the overall industrial framework and improving carbon emission efficiency (Ding J., 2019)[16]. Regarding policy facilitation, the evolution of green finance is frequently bolstered by governmental incentives, which can encourage enterprises to curtail carbon emissions through green financial strategies, such as tax benefits, financial grants, and dedicated green credit lines (Meng Yuxin, 2023)[17]. Concurrently, stringent environmental regulations increase the challenges faced by high-pollution and high-energy-consuming enterprises in securing financing, compelling them to enhance their carbon output efficiency.

Considering the preceding analysis, the following hypothesis is posited:

Hypothesis 1: Green finance enhances carbon emission efficiency.

In its nascent stages, the degree of green technological innovation was relatively modest, and advancements in technology could yield substantial reductions in emissions. Green finance avails essential capital for green technologies and projects through mechanisms such as loans and investments. Green technological innovation fosters improvements in labor productivity and resource allocation efficiency by optimizing input-output structures, consequently enhancing carbon emission efficiency. Furthermore, green technology innovation serves as a catalyst for industrial transformation, facilitating a shift in the industrial and energy structures from high-carbon to low-carbon (Xu Yingqi, 2023)[18]. As green technological innovation progresses, the influence of green finance on carbon emission productivity may diminish, likely due to the emergence of a broader array of green technology options, resulting in heightened competition. As the market reaches a saturation point, financial institutions may become more discerning in their evaluation of high-potential green technologies, necessitating greater innovation to distinguish new technologies. When the level of green technological invention ascends once more, the impact of green finance on carbon emission efficacy may be revitalized, potentially coinciding with technological breakthroughs that significantly enhance energy utilization efficiency, while established technologies achieve widespread deployment, thus yielding greater environmental benefits and further improving carbon emission efficacy.

Considering the preceding analysis, the following hypothesis is posited:

Hypothesis 2: Green technology innovation acts as a threshold factor in the relationship between green finance and carbon emission efficiency.

3. Modeling

In order to exam the effect of green finance on carbon emission productivity, this paper constructs the following model:

$$co_{2_{it}} = \alpha_0 + \alpha_1 GF_{it} + \sum \gamma_j Controls_{it} + \mu_{it} + \lambda_{it} + \varepsilon_{it} \quad (1)$$

Where CO_2 represents the carbon emission efficiency, and GF represents the level of green financial development, and$Controls$ represents the control variables, andε_{it} is the error disturbance term, andμ_{it} is the individual fixed effect, andλ_{it} are time fixed effects, subscripts$i$ and$t$ represent region and time, respectively.

In conjunction with the preceding analysis, to evaluate the threshold effect of green technological advancement, a model is formulated based on the method proposed by Hansen (1999)[19], treating green technological advancement as the threshold variable, with the assumption that there is no dual threshold present.

$$co_{2_{it}} = \alpha_0 + \alpha_1 GF_{it} I(GT \le \gamma) + \alpha_1 GF_{it} I(GT > \gamma) + \alpha_i Controls_{it} + \lambda_i + \mu_{it} + \varepsilon_{it} \quad (2)$$

Where I( ) is a schematic function that takes the value 1 when the condition in the parentheses holds and 0 otherwise.GT is the threshold variable green technology innovation, and γ is the threshold value, and the rest as above.

3.1 Selection of indicators

(1) Explained Variables

The clarificatory variable is the carbon emission productivity (CO2), assessed utilizing the super-efficiency SBM model. A salient attribute of the superlative SBM model is its capability to dissect and order efficacious decision-making units whilst accounting for non-preferred outputs, thereby enhancing the precision of the efficiency assessment. Its mathematical formulation is delineated as follows:

$$\min \rho = \begin{cases} \dfrac{\frac{1}{m}\sum_{i=1}^{m}\left(\bar{x}/x_{ik}\right)}{\frac{1}{r_1+r_2}\left[\sum_{s=1}^{r_1}\overline{y^d}/y_{sk}^d + \sum_{q=1}^{r_2}\overline{y^u}/y_{qk}^u\right]} \\ \bar{x} \ge \sum_{j=1,\ne k}^{n} x_{ij}\lambda_j ; \overline{y^d} \le \sum_{j=1,\ne k}^{n} y_{sj}^d \lambda_j \\ \overline{y^d} \ge \sum_{j=1,\ne k}^{n} y_{qj}^d \lambda_j ; \bar{x} \ge x_k \\ \overline{y^d} \le y_k^d ; \overline{y^u} \ge y_k^u \end{cases}$$

$$\lambda_j \ge 0, i = 1,2,\ldots, m; j = 1,2,\ldots n; s = 1,2,\ldots, r_1; q = 1,2,\ldots, r_2; \quad (3)$$

Where ρ is the carbon emission efficiency, and n represent the count of decision-making entities, and m signify the input, and r_1 denote the preferred output, and r_2 indicate the undesired output, and x is the compoenet of the input matrix, the y^d is the element of the desired output matrix, and y^u are the elements in the non-expected output matrix.

Referring to the study of Tian Yun and Lin Zijuan (2022)[20] , the carbon emission efficiency index system based on inputs and outputs is constructed, see Table 1.

Table 1: Carbon emission efficiency indicator system

Type of indicator	Level 1 indicators	Secondary indicators
Input indicator 1	principal	Capital stock (billions of dollars)
Input indicator 2	labor force	Overall count of workers in the three sectors (10,000 persons)
Input indicator 3	renewable energy	Total energy consumption (tons of standard coal)
Output indicator 1	Expected outputs	GDP (billions of dollars)
Output indicator 2	Non-expected outputs	Carbon emissions (tons)

(2) Core explanatory variables

The pivotal explanatory variable is green finance (GF). Drawing on the research by Yin Ziqiang et al. (2021)[21], an index system is constructed encompassing four facets: green lending, green equities, green investment, and green insurance. The entropy method is employed to gauge the degree of green financial advancement, as illustrated in Table 2.

Table 2: Green finance indicator system

Primary indicators	Secondary indicators	Definition of indicators	causality
green finance	green credit	Interest Expenditures of Energy-intensive Industrial Industries/Total Industrial Interest Expenditures	negative
	green securities	Value of the six most energy-intensive A-shares/total A-share market capitalization	negative
	green insurance	Agricultural insurance earnings/gross agricultural output	positive
	green investment	Investment in environmental pollution control/GDP	positive

(3) Threshold variables

Green Technology Innovation (GT). Referring to the study of Qu et al. (2021)[22] , green technology advancement is measured by the proportion of the number of granted green patents to the total number of patents granted in their year.

(4) Control variables

To avert potential endogeneity issues stemming from the exclusion of significant control variables, four controls are chosen, referencing extant literature. These include the degree of economic growth (measured by per capita GDP, denoted as PGDP), the configuration of the industrial sector (quantified by the proportion of the tertiary sector in GDP, labeled as IS), the extent of external openness (assessed by the proportion of total imports and exports to GDP, signified as OPL), and governmental intervention (evaluated by the fraction of government fiscal expenditures within GDP, indicated as GOV).

3.2 Data processing and sources

Data concerning green technology innovation are gathered at the provincial echelon by aggregating the figures by province based on enterprise information at the site of patent applications. Considering the availability of data, this study opts for the panel data encompassing 30 provinces (excluding Hong Kong, Macao, and Taiwan) in China from 2005 to 2021. The pertinent data are sourced from the China Statistical Yearbook, China Energy Statistical Yearbook, China Industrial Statistical Yearbook, China Financial Yearbook, China Insurance Yearbook, China Environmental

Statistical Yearbook, and the Guotaian CSMAR database covering the years 2006 to 2022. To address certain gaps in the data, the interpolation technique was employed for completion.

4. Empirical analysis

4.1 Descriptive statistical analysis

As illustrated in Table 3, the average value of carbon emission efficiency stands at 0.417, with a standard deviation of 0.257, signifying disparities in carbon emission efficiency across various regions. The minimum value of the overall green financial development level is recorded at 0.064, while the maximum value reaches 0.790, highlighting substantial variations among the regions.

Table 3: Descriptive statistics

variant	observed value	average value	standard deviation	minimum value	maximum values
GF	510	0.190	0.086	0.064	0.790
CO_2	510	0.417	0.257	0.165	1.532
GT	510	0.082	0.025	0.025	0.146
PGDP	510	4.462	2.951	0.522	18.753
IS	510	0.469	0.093	0.298	0.837
OPL	510	0.306	0.353	0.008	1.711
GOV	510	0.238	0.108	0.092	0.758

4.2 Benchmark regression

(1) Fixed effects regression results

Following the Hausman test, Table 4 presents the foundational regression outcomes of the model. This regression incorporates controls for both region and year. The R^2 value is 0.631, indicating a robust model fit. As shown in column (2), the estimated coefficient for green finance is 0.606, which is statistically significant at the 1% level, suggesting that green finance plays a notable role in improving carbon emission productivity. Potential explanations for this include green finance facilitating capital allocation towards eco-friendly industries by guiding the movement of funds, the advancement of environmental conservation and clean energy technologies, and governmental incentives providing financial backing to bolster carbon emission efficacy. Regarding the control variables, the level of economic development exhibits a favorable relationship at the 10% significance level, significantly contributing to carbon output efficiency. This is likely due to economic development fostering technological innovation and advancement, alongside the development of green and low-carbon technologies, which can diminish carbon emissions per unit of energy consumption, thereby enhancing carbon emission efficiency.

(2) Regression results of secondary indicators of green finance

Utilizing the secondary indicators of green finance, such as green credit, green securities, green investment, and green insurance, a fixed effect regression analysis is conducted on carbon emission efficiency. As depicted in Table 5, both green investment and green insurance significantly contribute to carbon emission efficiency. Green investment channels capital towards low-carbon technologies and services, facilitating their development and expansion, thereby enhancing overall carbon emission efficiency. Meanwhile, green insurance incentivizes enterprises to adopt more rigorous environmental protection measures, reducing carbon outputs and improving carbon emission efficacy through the provision of insurance products aligned with environmental standards.

Table 4: Benchmark regression results

variant	(1)	(2)	(3)	(4)
GF	0.584** (2.42)	0.606*** (2.96)	0.618** (2.18)	0.606*** (2.96)
PGDP	--	0.022* (1.99)	-0.014*** (-3.96)	0.022* (1.99)
IS	--	-0.212 (-0.85)	-0.591*** (-3.55)	-0.212 (-0.85)
OPL	--	0.197 (1.25)	0.062 (0.42)	0.197 (1.25)
GOV	--	-0.113 (-0.63)	-0.557*** (-2.77)	-0.113 (-0.63)
C	0.459*** (11.45)	0.450** (2.46)	0.754*** (8.9)	0.450** (2.46)
Year	yes	yes	no	yes
ID	yes	no	yes	yes
R^2	0.578	0.631	0.539	0.631
N	510	510	510	510

Note: ***, ** and * indicate significant at the 1%, 5% and 10% levels, respectively, with t-values in parentheses. The following table is the same

Table 5: Results of regression of secondary indicators on carbon emission efficiency

variant	(1)	(2)	(3)	(4)
green credit	-0.671* (-1.94)	--	--	--
green securities	--	-0.004 (-0.07)	--	--
green investment	--	--	0.260 (0.32)	--
green insurance	--	--	--	0.050*** (3.45)
PGDP	0.031* (1.70)	0.034* (1.72)	0.034* (1.70)	0.019* (1.82)
IS	-0.345 (-1.15)	-0.342 (-1.11)	-0.346 (-1.11)	-0.124 (-0.45)
OPL	0.164 (0.94)	0.147 (0.82)	0.146 (0.81)	0.217 (1.38)
GOV	0.044 (0.33)	0.076 (0.50)	0.074 (0.51)	-0.137 (-0.73)
C	0.771*** (3.01)	0.558*** (2.81)	0.556*** (2.85)	0.493** (2.66)
Year	yes	yes	yes	yes
ID	yes	yes	yes	yes
R^2	0.567	0.554	0.554	0.645
N	510	510	510	510

4.3 Robustness tests

Table 6: Robustness test regression results

variant	(1) OLS	(2) Instrumental variable-2sls method regression	(3) Bilateral indentation
GF	0.606*** (7.78)	0.738*** (7.59)	0.601** (2.31)
PGDP	0.022*** (4.42)	0.019*** (4.34)	0.021 (1.64)
IS	-0.212 (-1.59)	-0.135 (-1.27)	-0.290 (-1.12)
OPL	0.197*** (3.62)	0.226*** (4.01)	0.179 (1.08)
GOV	-0.113 (-1.17)	-0.120 (-1.57)	-0.138 (-0.72)
C	0.976*** (4.87)	0.516** (2.47)	0.495** (2.66)
Year	yes	yes	yes
ID	yes	yes	yes
R^2	0.958	0.966	0.613
N	510	510	510

Panel fixed effects are used in the basic regression to carry out the regression, in order to test the robustness of the regression results, OLS method regression, instrumental variables regression, bilateral reduced-tailed post regression, the regression results are shown in Table 6. It can be seen that green finance has a significant role in promoting the efficiency of carbon emissions, confirming the validity of the previous results.

4.4 Analysis of regional heterogeneity

The analysis of regional diversity reveals that China's diverse regions exhibit substantial differences in geography, economic growth rates, and governmental policy frameworks. Following a regression analysis segmented into eastern, central, and western regions, the findings presented in Table 7 indicate that the estimated coefficients are markedly positive in the east, significantly negative in the central region, and negative in the west. The development of green finance holds a key position in advancing carbon emission efficacy in the eastern region, likely due to its robust economic foundation, which allows for the effective introduction and adoption of advanced low-carbon technologies both domestically and internationally. This capacity facilitates the widespread application of these technologies, thereby bolstering carbon emission efficiency. Conversely, in the central and western regions, green finance appears to exert a detrimental effect on carbon emission productivity. This may stem from the relatively sluggish economic progression in these areas compared to the east, coupled with inadequate governmental oversight that hampers the effective enforcement and implementation of green finance initiatives. As a result, funds struggle to reach genuine green investments, and the absence of essential transparency and supervisory mechanisms undermines the effective utilization of these resources, ultimately impacting carbon emission efficacy.

Table 7: Results of heterogeneity test

variant	(1) East	(2) Medium	(3) West
GF	1.042*** (4.96)	-0.375** (-2.47)	-0.140 (-1.45)
PGDP	0.016 (0.88)	-0.056 (-1.41)	0.015 (0.67)
IS	0.208 (0.37)	-0.320 (-0.83)	-0.196 (-1.10)
OPL	0.237 (1.16)	0.470*** (6.96)	-0.076 (-0.46)
GOV	-0.916 (-1.23)	-1.765*(-2.07)	0.002 (0.02)
C	0.370 (0.82)	0.932*** (4.83)	0.465*** (5.47)
Year	yes	yes	yes
ID	yes	yes	yes
R^2	0.675	0.794	0.798
N	187	187	187

4.5 Threshold effect test

Building upon the prior analysis, which indicates that green technological advancement may serve a threshold function in the connection between eco-friendly finance and carbon output productivity, green technological advancement is employed as a threshold variable to conduct a threshold effect examination. The findings of the threshold effect significance test are presented in Table 8. As illustrated in Table 8, a dual threshold is evident, with threshold values identified at 0.0451 (significant at the 1% significance level) and 0.1269 (significant at the 10% significance level) respectively.

Table 8: Threshold effect test results

Threshold variables	Number of thresholds	threshold value	F-value	P-value	10% threshold	5% threshold	1% threshold
GT	single threshold	0.0451***	43.38	0.0067	23.5292	31.6595	41.1018
	double threshold	0.1269*	24.44	0.0600	20.0852	25.9672	33.5029
	triple threshold	0.0972	11.97	0.5333	27.1384	33.1553	45.8906

Table 9 exhibits the outcomes of the panel threshold model regression. As green technology innovation advances, the propelling impact of green finance on carbon emission productivity displays a pattern of initially ascending, subsequently diminishing, and then ascending anew. When the degree of green technology advancement is beneath 0.0451, the impetus exerted by green finance on carbon emission productivity is most potent. This is likely due to the fact that at lower levels of green technology innovation, the financial and policy backing of green finance can be concentrated on a select number of promising ventures, fostering the enhancement of resource allocation efficacy and consequently boosting carbon emission efficiency. Beyond this threshold, the propelling effect gradually wanes. However, when green technology innovation surpasses 0.1269, the propelling effect on carbon emission efficiency gradually intensifies once more. This might be attributable to the large-scale application and production of advanced technologies, whereby the support of green finance can further amplify economies of scale, decrease unit costs, and elevate carbon emission productivity.

Table 9: Threshold regression results

variant	estimated coefficient	T-value
GT<0.0451	0.8858***	8.99
0.0451<GT<0.1269	0.3450***	4.90
GT>0.1269	0.4635***	6.71
PGDP	-0.010***	-4.05
IS	-0.670***	-7.76
OPL	0.043*	1.66
GOV	-0.542***	-8.27
C	0.811***	22.17
Year	yes	yes
ID	yes	yes

5. Conclusions and insights

5.1 Main findings

Drawing upon panel data from 30 provinces in China, spanning the years 2005 to 2021, this investigation employs the entropy methodology to ascertain the extent of green finance development and constructs a two-way fixed effects model to empirically analyze the impact of green finance advancement on carbon output efficacy. The following conclusions are derived: firstly, green finance holds a pivotal position in augmenting carbon emission productivity. Secondly, a dual threshold regarding green technology innovation is discerned; as advancements in green technology innovation transpire, the influence of green finance on enhancing carbon emission efficacy exhibits a trajectory characterized by an initial rise, a subsequent decline, and a final resurgence. Thirdly, regional analysis

indicates that green finance in the eastern region significantly enhances carbon emission efficiency and reduces carbon output density, whereas the central and western regions may display diminished carbon emission efficiency, attributable to sluggish economic growth and inadequate governmental oversight.

5.2 Policy implications

First, amplify investments in green financial endeavors. Through fiscal backing and tax incentives, businesses and financial institutions ought to be motivated to engage in sustainable financial practices. It is essential to cultivate a diverse array of green financial products, augment financing instruments, and optimize capital allocation, thereby facilitating technological metamorphosis and industrial enhancement. This approach will truncate the latency for carbon emission reduction effects to manifest and bolster the efficacy of emission reductions. Corresponding policies and regulations should be instituted to furnish institutional assurances that funds are genuinely allocated for environmental preservation and sustainable initiatives, aiding in the achievement of the "dual-carbon" objective.

Second, perpetually advance the innovation of green technologies. We shall guide and bolster the research and development of eco-friendly technologies, amplifying medium- and long-term financial backing, while urging enterprises to undertake substantial innovations in sustainability. Concurrently, it remains imperative to fortify and refine the regulatory framework governing green finance, standardizing and constraining financial investment behaviors to ensure that green finance persistently enhances carbon emission productivity.

Third, the execution of tailored regional policies pertaining to green finance is crucial. Given the disparate natural and economic conditions across China's regions, along with variations in production factors and technological capabilities, the eastern region should fervently promote the innovation of green financial systems, leveraging its role as a demonstrative force to enhance carbon emission productivity. Meanwhile, the central and western regions should prioritize ecological conservation while advancing green technologies, expediting their transition to sustainable practices and fostering clean energy and low-carbon technologies.

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