World Journal of Economics and Business Research
Print ISSN: 2960-0073
Online ISSN: 2960-0081
DOI: https://doi.org/10.61784/wjebr3060

EMPIRICAL ANALYSIS ON THE EFFECT AND MECHANISM OF GREEN FINANCE RELATING TO REDUCTION AND CARBON EMISSION REDUCTION RELYING ON THE EMPIRICAL EVIDENCE FROM CHINESE LISTED COMPANIES

ZiMo Chen
School of Accounting, Shanghai University of International Business and Economics, Shanghai 201620, China.
Corresponding Email: 23043019@suibe.edu.cn

Abstract: In the process of implementing the "dual-carbon" strategy, research on whether green finance can truly translate into emission reduction effects and its conversion mechanism is crucial for testing green finance policies. The present study takes A-share listed non-financial enterprises in China from 2011 to 2022 as samples, matches enterprise emission data of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and soot, and constructs a "firm-year" green finance index built on seven types of tools including green credit and green bonds to systematically examine the impact of green finance on corporate pollution reduction and carbon emission reduction. Baseline regression results show that for each 1-unit rise in the green finance index, the logarithm of total corporate pollutant emissions decreases by an average of 0.366, and this conclusion stays robust after instrumental variable and robustness examinations. Mechanism analysis reveals that green finance exerts its effects through a dual-pathway of alleviating financing constraints and promoting green technological innovation: on one hand, it significantly reduces the SA index, providing low-cost funds for corporate green investments; on the other hand, it significantly increases the quantity of applications submitted for green utility model patents, facilitating process upgrading and end-of-pipe treatment. Heterogeneity tests reveal that the emission reduction effect of green finance stands out more in non-state-owned enterprises (non-SOEs), eastern regions, and the manufacturing industry, presenting a pattern of "non-SOEs outperforming SOEs, eastern regions outperforming central and western regions, and manufacturing outperforming non-manufacturing". This study provides micro-level evidence for constructing a precise and efficient green finance support system, and also offers actionable policy references for accomplishing the "dual-carbon" goals.
Keywords: Green finance; Pollution control and carbon emission reduction; Funding constraints; Green tech innovation; Corporate heterogeneity

1 INTRODUCTION

Escalating greenhouse gas emissions and the resultant climate crisis—manifesting itself by extreme weather events, rising sea levels, and resource scarcity—highlight the urgent need for transformative solutions to ensure sustainable development. Against the backdrop of in-depth changes in the global governance system and accelerated advancement of the "dual-carbon" strategy, China, as the world's top carbon emitter, is facing the major era proposition of coordinated governance pertaining to pollution reduction and carbon emission reduction. Green finance, via market-oriented tools such as credit facilities and funds, serves as an important means to promote structural transformation after China's economic development stepped into the "new normal", and is regarded as a key fulcrum to drive enterprises' pollution control and carbon mitigation [1]. As specified in the Official Report of the 19th National Congress of China, green finance is an inevitable path to promote green economic transformation, a key measure to address unbalanced and inadequate regional economic development, and an important impetus for high-quality economic development; thus, further development of green finance should be promoted [2].

Existing scholars have carried out a series of studies on the effect of green finance on corporate production and operation activities. Studies shows that green finance promotes the expansion of green total factor productivity by improving the efficiency in the allocation of financial resources [3]. At the same time, society's demand for pollution control and carbon mitigation is increasing. With the continuous improvement of green GDP assessment methods and the implementation of strict environmental regulations, local governments attach greater importance to the ecological benefits of economic growth. Therefore, promoting corporate pollution reduction and carbon emission reduction is an inevitable requirement for implementing the "dual-carbon" strategy and a practical need to respond to the social concern of pollution reduction and carbon emission reduction.

In practice, when the focus of green finance policies shifts from "credit scale" to "corporate pollution and carbon reduction levels", whether the growth of green finance development can promote the advancement of corporate pollution and carbon emissions reduction levels has become the first criterion for measuring the effectiveness of the "dual-carbon" strategy. The core of this issue lies in the transmission mechanism of green finance on the coordination of corporate pollution reduction and carbon emission reduction.

1.1 Literature Review

Relevant studies on this research topic can be summarized into two levels:
Macro-level studies: Existing research measures green finance using green finance indexes and tests its impact on the abatement of pollution and carbon.For example,using panel data of 30 provinces in China spanning 2011 to 2022, Wang et al. introduced green finance indexes as mechanism variables and found that the combination of digital and real economies directly promotes the synergistic function of pollutant abatement and carbon emission reduction . In addition, some scholars have taken green finance reform pilot zones as research objects to evaluate their impact. Among them, Zhang & Hu constructed a general equilibrium model to systematically explain the theoretical association between green finance and pollution/carbon reduction, and used panel data of 281 Chinese cities from 2011 to 2022 to empirically examine the impact along with the working mechanism of green finance reform pilot zone policies concerning urban pollution and carbon emission reduction using a staggered difference-in-differences (DID) model [3]. Based on the current development status of China's pilot zones for green finance reform, Wang et al. proposed that local governments should strengthen the establishment of guarantee mechanisms and innovate green financial products based on local economic advantages to better promote green finance practice[4].
Micro-level studies: Researchers have probed into the effect of green finance on corporate behavior. In terms of factor productivity, green finance significantly facilitates the enhancement of corporate factor productivity. For example, Liu et al. undertaken a quasi-natural experiment drawing on the Green Credit Guidelines and found that green credit significantly improves the factor productivity of high-pollution enterprises[5].Regarding financing constraints,green finance can drive corporate pollution reduction and carbon reduction by reducing financing constraints. Using the MLF collateral expansion event, Yan et al. confirmed that relevant policies ultimately reduce corporate emissions by lowering financing costs and improving environmental information disclosure quality, with more significant effects in enterprises with high financing constraints and in the growth stage [6]. Regarding the "dual-carbon" goal, enterprises need to promote digital transformation, and the operation of carbon emission trading mechanisms has an important impact on corporate production, strategy, and technological innovation. Relying on data of listed firms in China's A - share market from 2007 to 2020, Liu et al. took the carbon emission trading policy regarded as a quasi-experiment and found that this policy promotes the digital transformation of enterprises in pilot areas, thereby better integrating the concept of green development with digital economy theory [7].

1.2 Research Gaps and Marginal Contributions

Although the above literature confirms that green finance promotes enterprise pollution abatement and carbon emission reduction from multiple dimensions, there are still two gaps: First, existing studies mainly measure the dependent variable (y) using city or industry averages, failing to fully verify the micro-level direct influence of the "green finance development level(x) → corporate pollution-carbon reduction coordination (y)", which makes it impossible to reliably verify policy effects. Second, although some studies have proposed two potential mediating mechanisms—"alleviation of financing constraints" and "green technological innovation"—most studies only focus on the city level or conduct single-mechanism tests, lacking the identification and comparison of the two pathways in the same micro sample, resulting in more macro-level studies and less micro-level evidence.
To fill these research voids, this study first analyzes the direct impact of green finance on corporate pollution reduction and carbon emission cut, and then examines the channels through which green finance drives corporate pollution and carbon reduction by alleviating financing constraints and boosting technological innovation—this constitutes the marginal contribution of this study.

2 THEORETICAL DISCUSSION AND RESEARCH PROPOSITIONS

2.1 Direct Effect of Green Finance on Corporate Pollution-Carbon Reduction Coordination

Green finance policies can guide capital factors to flow into the sector of energy conservation and environmental protection, promote regional industrial transition and upgrading by encouraging the advancement of clean industries and restricting high-polluting enterprises [8], and advance the economy's green-oriented and low-carbon transformation [9]. At the same time, through diversified types of financial tools such as green credit facilities and green bonds, green finance reallocates scarce resources from "high-energy-consuming, high-polluting, and overcapacity" industries to green and low-carbon projects, thereby directly curbing corporate pollutant and carbon emissions and improving the standardization of enterprises' use of carbon emission rights, energy use rights, and pollution discharge rights. On this basis, the following hypothesis is put forward:
H1: Green finance significantly improves the level of corporate pollution-carbon reduction coordination; that is, the higher the intensity of green finance, the lower the pollutant and carbon emissions per unit output of enterprises.

2.2 Mechanism Routes Through Which Green Finance Boosts Corporate Pollution-Carbon Reduction Coordination

The synergetic function of green finance in corporate pollution and carbon reduction not only manifests as a direct effect but also exerts its action through the two mediating pathways that follow:
2.2.1 Financing constraint alleviation mechanism

Green finance forms an effective financing constraint mechanism through differentiated interest rate policies and green supervision measures, promoting corporate green transformation [3]. Specifically, at the economic performance level, enterprises can obtain financing through green finance, sending a signal to the government and the public that they actively fulfill green social responsibilities. This helps enterprises gain a good reputation, enhance the confidence and trust of stakeholders, attract more investors, reduce financing constraints, and ultimately improve corporate competitiveness and economic benefits [10].

Meanwhile, Chen took Chinese commercial banks and listed enterprises from 2014 to 2023 as research objects, constructed a bank fintech index and corporate sustainability indicators using machine learning algorithms, and found that fintech promotes corporate sustainability through financing and governance effects [11]. By selecting Chinese A-share listed companies that issued green bonds and those that issued ordinary bonds but not green bonds from 2016 to 2021, Ren further found that green bond issuance improves corporate ESG performance by alleviating financing constraints and reducing agency costs [12].

For green enterprises, green finance reduces the financing costs and thresholds of green projects through green credit quotas and green bond special channels, thereby alleviating financing constraints for their pollution and carbon reduction investments. In contrast, for polluting enterprises, green finance implements punitive monetary policies to strictly restrict the financing channels for their high-polluting projects. This differentiated financing constraint mechanism encourages green enterprises to update clean equipment, expand environmental protection investments, and achieve both end-of-pipe treatment and source prevention of pollution, thereby reducing pollutant and carbon emissions simultaneously and promoting enterprises to choose a green development path. Using this as a basis, the following hypothesis is put forward:

H2: Green finance indirectly improves the level of corporate pollution-carbon reduction coordination through the mitigation of financing constraints for enterprises.

2.2.2 Green technological innovation promotion mechanism

The ability of technological innovation is affected by many factors, among which R&D investment is the main driving factor. The capital flow of green finance encourages enterprises to develop green technologies, strengthen technological innovation, and create a competitive environment favorable for enhancing the level of green technological innovation. Green technological innovation also promotes the channeling of economic resources to green enterprises, optimizes the industrial structure, helps enterprises create new products and services, and drives high-quality economic development [13].

Using provincial panel data across China from 2018 to 2022, Ren constructed a green low-carbon development index and found through panel regression and mediating effect models that green finance exhibits a significant positive impact on green low-carbon economic development process, and indirectly empowers corporate green development by accelerating technological innovation and the upgrading of industrial structure[14]. From the dual viewpoints of technological innovation and environmental attention, Mao et al. utilized data from 30 provinces (municipalities, autonomous regions) in China from 2011 to 2022 and uncovered that green finance promotes the "quantity and quality improvement" of technological innovation, thereby driving the development of new-quality productive forces [15]. With the green finance reform and innovation policy as a reference, Zhang et al. constructed multi-period DID and DDD models and found that green finance significantly improves corporate total factor productivity using data of Chinese A-share listed companies from 2010 to 2021 [16]. In addition, Meng et al. utilized the entropy method to examine the mechanism of green finance accelerating high-quality economic development, from the dual dimensions of technological innovation and industrial structure upgrading, and their empirical results showed that technological innovation and industrial structure upgrading play key roles in green finance propelling high-quality economic development[17].

Green finance provides stable and low-cost capital for corporate green technology R&D through market-oriented means such as preferential interest rates and government subsidies, thereby increasing the enthusiasm and success rate of corporate technological innovation. With the support of green finance, enterprises significantly strengthen their green technological innovation capabilities, and further augment the synergistic effect of pollution and carbon reduction through process upgrading, equipment renewal, and product restructuring. Drawing upon this, the following hypothesis is put forward:

H3: Green finance indirectly improves the level of corporate pollution-carbon reduction coordination by promoting corporate green technological innovation.

3 MODEL SPECIFICATION AND VARIABLE SELECTION

Green finance curbs pollutant emissions and achieves corporate - level pollution reduction by optimizing financial resource allocation, reducing corporate financing costs, and encouraging green technological innovation. Meanwhile, pollution levels are also affected by internal corporate characteristics such as scale, profitability, growth, and age. Based on existing studies, this study constructs the following dynamic panel econometric model:

$$Pollutant_{i,t} = \alpha_0 + \alpha_1 Pollutant_{i,t-1} + \beta GreenFinance_{i,t} + \gamma \sum Control_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

In this model, $Pollutant_{i,t}$ represents the pollutant discharge level of an enterprise in a certain year; $Pollutant_{i,t-1}$ is the lagged one - period pollutant emission of enterprise i; $GreenFinance_{i,t}$ is the green finance index, reflecting the degree of green financial resources obtained by enterprise i (or its location) in year t; $Control_{i,t}$ stands for firm size (size) and

equity multiplier (em) are included as control variables, firm age (firmage), and firm growth (growth); μ_i denotes firm fixed effects; λ_t represents year fixed effects; $\alpha_0,\alpha_1,\beta,\gamma$ are estimated coefficients; and $\varepsilon_{i,t}$ is the idiosyncratic error term.

3.1 Variable Selection

3.2.1 Dependent variable

Pollutant Emission (pollution): Referring to common practices in existing studies on industrial pollutants, this study employs the natural logarithm of the total emissions of three major air pollutants (SO_2, NO_x, and soot) as the core dependent variable to reflect the total pollution emission intensity of enterprises.

3.2.2 Core independent variable

Green Finance Index (GreenFin): Green finance refers to financial services offered to sectors like environmental protection, energy conservation, and clean energy, aiming to optimize resource utilization efficiency, strengthen environmental governance, and steer resources away from high-polluting and high-energy-consuming industries toward clean industrial sectors that feature advanced technologies [2]. Internationally recognized definitions further clarify its connotation: the World Economic Forum defines it as "organized financial activity created to ensure a better environmental outcome," while UN ESCAP describes it as "support for environment-oriented technologies, projects, industries or businesses."[18]

Green finance in China is primarily composed of green credit, green securities, green insurance, and green investment. Based on the definition of green finance's multi-dimensional connotation in existing studies [2], this study constructs a green finance development index from 7 core dimensions—green credit, green investment, green insurance, green bonds, green support, green funds, and green equity—using the entropy method to measure the regional green finance development level at the "firm-year" level. A higher green finance index indicates a higher level of regional green finance. Considering the lag effect of green finance, this study uses the lagged one-period green finance index to more accurately verify its impact on corporate the mitigation of pollution and carbon.

3.2.3 Control variables

To manage other factors that may affect corporate pollutant emissions, this study selects five indicators as control variables, grouped into three categories:

1. Scale and Capital Structure: firm size (size), equity multiplier (em);
2. Profitability and Growth: return on assets (roa), firm growth (growth);
3. Life Cycle: firm age (firmage).
4. 3.2.4 Mechanism Variables

To comprehensively analyze the supportive role of green finance in promoting corporate pollution and carbon reduction, it is necessary to systematically test the internal mechanism of green finance on corporate pollution and carbon reduction:

1. Financing Constraint: Measured by the SA Index (Hadlock & Pierce SA Index), where a smaller value indicates weaker financing constraints (and thus a higher magnitude of pollution control and carbon reduction);
2. Green Technological Innovation: Measured by the natural logarithm of the total number of green utility model patent applications of enterprises in the current year.

The specific definitions of all variables are shown in Table 1.

Table 1 Operational Definition and Description of Variables

Variable Name	Variable Symbol	Variable Definition
Pollution Emission	pollution	Natural logarithm of total emissions of air pollutants (SO_2 + NO_x + soot)
Green Finance Index	GreenFin	Comprehensive green finance index synthesized by the entropy method (one-period lagged version)
Firm Size	size	Natural logarithm of total assets at the end of the year
Equity Multiplier	em	Total Assets at the End of the Year / Owner's Equity at the End of the Year
Return on Assets	roa	Net profit / Total assets at the fiscal year-end
Firm Age	firmage	ln (Current year - Founding year + 1)
Firm Growth	growth	[Operating income (current year) - Operating income (previous year)] / Operating income (previous year)
Ownership Nature	soe	1 = State-owned enterprise (SOE), 0 = Non-SOE
Eastern Region	east	1 = Enterprise located in eastern China, 0 = Otherwise
Western Region	west	1 = Enterprise located in western China, 0 = Otherwise
Central Region	mid	1 = Enterprise located in central China, 0 = Otherwise

Manufacturing Industry	manufacturing	1 = Enterprise in manufacturing industry, 0 = Otherwise
Financing Constraint	SA Index	Hadlock & Pierce SA Index (smaller value = weaker constraint)
Green Innovation	ln_green_patent	Natural logarithm of the number of green utility model patents applied for in the current year
Year Fixed Effects	year_fe	Year dummy variable

4 RESULTS

4.1 Descriptive Statistics

Table 2 reports the descriptive statistics of the primary variables. For pollutant emission (pollution), the mean value is 1.203, the population standard deviation is 1.066, the minimum figure is 0, and the maximum figure is 6.227, indicating significant differences in statistics in pollutant emissions among enterprises. The green finance index (GreenFin) has a mean value of 0.390, a standard deviation of 0.123, and a value range of 0.013-0.719, showing that the support of green finance for corporate pollution and carbon reduction is generally moderate and relatively concentrated. The mean value of firm size (size) is 22.526 with a standard deviation of 1.411; similarly, other variables also show varying degrees of differences. Except for the equity multiplier (em) and firm growth (growth), the standard deviations across all variables are less than 1.5, indicating a low degree of data dispersion.

Table 2 Descriptive Statistics for Key Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
pollution	37174	1.203	1.066	0	6.227
GreenFin	18640	0.390	0.123	0.013	0.719
size	18640	22.526	1.411	17.641	30.081
em	18640	2.502	9.292	-865.898	417.253
roa	18640	0.020	0.147	-14.302	0.786
firmage	18640	3.022	0.317	1.099	4.290
growth	18622	1.029	24.526	-48.417	2354.549

4.2 Baseline Regression Findings

Table 3 presents the baseline regression results of the green finance index on corporate pollutant emissions (pollution). The regression controls for firm size (size), equity multiplier (em), return on assets (roa), firm age (firmage), firm growth (growth), and year fixed effects.

The coefficient of the core independent variable (GreenFin) is -0.366, which is significant at the 5% level. This indicates that for each 1-unit increase in the green finance index, corporate pollutant emissions decrease by an average of 0.366 units, verifying the inhibitory effect of green finance on pollution mitigation and verifying Hypothesis H1.

Regarding control variables: The coefficient of firm size (size) is 0.066, significant at the 1% level, indicating that larger enterprises have higher pollution emission levels; the coefficients of equity multiplier (em), return on assets (roa), and firm age (firmage) are not significant, suggesting that their marginal impact on pollutant emissions is limited under the baseline setting.

Table 3 Baseline Regression Results (Dependent Variable: pollution)

Variable	Coefficient	Std. Error
GreenFin	-0.366**	0.183
size	0.066***	0.012

em	0.001	0.001
roa	0.055	0.036
firmage	-0.093	0.102
growth	0.000	0.000
Constant	-0.381	0.373
Observations	15481	—
R-squared	0.429	—
Firm FE	YES	—
Year FE	YES	—

*Note: *** p<0.01, ** p<0.05, * p<0.1; Standard errors are reported in parentheses.

4.3 Mechanism Test Results

4.3.1 Financing constraint alleviation mechanism

Table 4's Column (1) shows that the estimated coefficient of the green finance index is -0.029 ($p < 0.1$), which demonstrates statistical significance negative, indicating the fact that green finance significantly reduces the corporate SA index—i.e., financing constraints are alleviated. This result is consistent with the "capital threshold" logic in green transformation: under traditional credit frameworks, green projects struggle to secure sufficient funds due to long payback periods and high risk premiums. However, green finance tools (e.g.green credit windows, discounted reloans) expand financial institutions' service scope, enabling banks to lend to green enterprises with lower risk weights and enterprises to obtain low-cost, long-term funds via green certification—shifting capital from "passive emission reduction" to "active pollution control". Thus, Hypothesis H2 is verified.

4.3.2 Green innovation-driven mechanism

Column (2) of Table 4 (ln_green_patent) shows that the coefficient of the green finance index is 0.453 ($p < 0.1$), and this is statistically significantly positive, indicating that green finance stimulates corporate green technological innovation. This is because green finance reduces R&D costs via subsidies and risk compensation, and boosts innovation returns through "green technology certification-credit quota linkage". With financing constraints eased, enterprises can afford R&D trial-and-error costs, increasing investment in clean processes and end-of-pipe equipment. Supporting policies (e.g., green patent rewards) further amplify innovation incentives. Thus, Hypothesis H3 is verified.

Table 4 Mechanism Test Results

Variable	(1) SA Index (Financing Constraint)	(2) ln_green_patent (Green Innovation)
GreenFin	-0.029*	0.453*
	(0.016)	(0.250)
Constant	-3.703***	5.533***
	(0.035)	(0.495)
Observations	18622	17113
R-squared	0.808	0.212
Controls	YES	YES
Firm FE	YES	YES

Year FE	YES	YES

*Note: *** p<0.01, ** p<0.05, * p<0.1; Standard errors are reported in parentheses.

4.4 Heterogeneity Analysis Results

4.4.1 Ownership heterogeneity

The first and second columns of Table 5 show that the green finance index has no significant impact on SOEs' pollutant emissions (coefficient = -0.065, p > 0.1) but significantly reduces non-SOEs' emissions (coefficient = -0.458, p < 0.05). This difference arises because non-SOEs face stricter financing constraints and are more sensitive to green finance's cost advantages, while SOEs have soft budget constraints and implicit government guarantees, reducing their sensitivity to green finance signals[19].

4.4.2 Regional heterogeneity

Column (3) within Table 5 shows that the green finance index inhibits pollutant emissions in eastern China (coefficient = -0.571, p < 0.05) but has no significant effect in central and western regions. Eastern China's mature financial markets, abundant green tools, and sound information disclosure enable enterprises to quickly convert green funds into emission reduction investments. In contrast, central and western regions lack financial infrastructure and policy implementation capacity, blocking policy transmission. Additionally, eastern China benefits from overlapping environmental policies (e.g., carbon trading, pollution permits), amplifying green finance's emission reduction effects.

4.4.3 Industry heterogeneity

Columns (6)-(7) of Table 5 show that green finance demonstrates a more significant emission reduction effect in manufacturing (coefficient = -0.654, p < 0.01) than in non-manufacturing (coefficient = -0.341, p > 0.1). Manufacturing enterprises are major polluters with strong green investment demand—green finance directly supports their process upgrading and equipment renewal. Non-manufacturing enterprises have lower emission intensity and scattered green investment needs, diluting green finance's incentive effects.

Table 5 Heterogeneity Analysis Results (Dependent Variable: pollution)

Variable	(1) SOEs	(2) Non-SOEs	(3) Eastern China	(4) Central China	(5) Western China	(6) Manufacturing	(7) Non-Manufacturing
GreenFin	-0.065	-0.458**	-0.571**	-0.434	-0.065	-0.654***	-0.341
	(0.316)	(0.229)	(0.276)	(0.506)	(0.316)	(0.237)	(0.297)
Constant	0.371	-1.170**	-0.397	-0.326	-0.371	-0.356	-1.237*
	(0.751)	(0.461)	(0.461)	(1.055)	(0.751)	(0.461)	(0.721)
Observations	6229	8880	9377	2588	6229	9833	5648
R-squared	0.479	0.375	0.406	0.451	0.479	0.444	0.424
Controls	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES

*Note: *** p<0.01, ** p<0.05, * p<0.1; Standard errors are reported in parentheses; "Controls refers to firm size (size), equity multiplier (em), return on assets (roa), firm age (firmage), and firm growth (growth)."

5 CONCLUSIONS

Green bonds and impact investing have become indispensable drivers for promoting sustainable finance. By 2024, they had attracted over USD 800 billion in funding annually, fully demonstrating that capital can not only generate competitive financial returns but also create significant environmental value.[20]This study takes Chinese A-share non-financial listed companies spanning 2011 to 2022 as samples, constructs a "firm-year" entropy method-constructed green finance index, and measures corporate pollution abatement and carbon emission reduction levels by the logarithm of total emissions of SO_2, NO_x, and soot. The primary research findings are as follows:

First, green finance shows a significant direct inhibitory effect on corporate pollutant emissions. After controlling for firm characteristics and year fixed effects, each 1-unit increase in the lagged green finance index reduces the logarithm of corporate pollutant emissions by an average of 0.366.

Second, green finance achieves synergistic emission reduction through the dual pathway of "alleviating financing constraints—promoting green technological innovation". It reduces the SA index to ease financing pressure and increases green utility model patent applications to enhance technological innovation.

Third, green finance's emission reduction effect exhibits significant heterogeneity: it is more prominent in non-SOEs, eastern regions, and manufacturing enterprises, but insignificant in SOEs, central/western regions, and non-manufacturing sectors.

5.1 Policy Recommendation

At the level of optimizing green finance practices, first of all, it is necessary to strengthen the intensity of differentiated support. This can be achieved by increasing the scale of green re loans, loan interest subsidies, and risk compensation, with a focus on tilting these supports toward the central and western parts of the country, as well as state-owned enterprises to decrease the financing costs associated with green projects. Meanwhile, efforts should be made to synchronously improve the construction of green project databases and the environmental information disclosure mechanism of enterprises, so as to provide a fundamental guarantee for precise support.

Secondly, it is essential to promote the coordinated development of the industrial chain system. On one hand, special funds should be established to support green technology R&D and equipment upgrading in the manufacturing industry; on the other hand, financial institutions should be guided to develop exclusive green credit products selected based on the characteristics of the non-manufacturing industry, so as to realize the coverage of green financial services across the entire industrial chain.

On this basis, it is required to establish and improve a dynamic monitoring system for emission reduction performance, build a dynamic management platform that links the use of green financial funds with the real-time emission data of enterprises, and connect the emission reduction performance with loan interest rates and credit limits. This will use market-oriented means to force the implementation of emission reduction responsibilities.

Finally, we need to strengthen the construction of policy synergy and data sharing mechanisms, promote the connection and integration of green finance policies with environmental policies such as carbon trading and pollution permits, and at the same time break down data barriers. By strengthening the data intercommunication between enterprise environmental information disclosure and financial supervision departments, a joint force for the development of green financial services can be formed.

5.2 Limitations and Future Research

This study has limitations: first, the sample focuses on large listed companies, and future research could include SMEs to expand generalizability; second, only two mechanism pathways are examined, and future work could incorporate government supervision, media attention, and supply chain pressure to explore "multi-stakeholder governance" scenarios.

Further, the studies may also conduct a cross-country analysis of how ESG and ENT practices could help to address the national economic policies, cultural attitudes, and local market conditions to overcome investment volatility.

In conclusion, this study provides micro-level evidence for green finance policy evaluation and offers references for building a precise, efficient green finance system, which is of great practical significance for securing the achievement of the "dual-carbon" goals.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Wang Y, Magnan M, Qiu Y. Going Green: An Analysis of Mutual Fund Investment and Green Innovation in the Context of China. Environmental and Resource Economics, 2025, 1-38. DOI: https://doi.org/10.1007/s10640-025-01035-4.

[2] Liu H K, He C. The mechanism and test of green finance promoting high-quality urban economic development: Empirical evidence from 272 prefecture-level cities in China. Investment Research, 2021, 40(07): 37-52.

[3] Zhang C, Hu Z G. How does green finance promote the coordinated advancement of urban pollution reduction and carbon emission reduction? Empirical evidence from green finance reform and innovation pilot zones. Commercial Research, 2025(02): 51-62.

[4] Wang K, Bai S Z, Tan J X, et al. The Impact of the Integration of Digital and Real Economies on the Synergistic Effect of Pollution Reduction and Carbon Emission Reduction in China. Research of Environmental Sciences, 2025, 38(08): 1668-1677.

[5] Liu J K, Liu J X, Chao Y. Green credit and low-carbon transformation: Capital integration or technological innovation? Evidence from a quasi-natural experiment. Journal of Quantitative & Technical Economics, 2024, 41(06): 151-171.

[6] Yan Y T, Shi G F, Xue J X. Research on the pollution and carbon reduction effect of structural monetary policy: A discussion on the structural effect of MLF collateral expansion. Modern Finance Research, 2025, 30(02): 61-71.

[7] Liu J Q, Yin G Y, Wu J H. Does the carbon emission trading policy promote corporate digital transformation?. Economic Perspectives, 2024(08): 75-92.

[8] Guo K S, Tian X X. Green technology and the green transformation of industrial development models. Tianjin Social Sciences, 2024(02): 99-107.
[9] Pan D Y, Chen C Q, Grubb M. Financial policies and low-carbon economic transformation: A study from the growth perspective. Journal of Financial Research, 2021(12): 1-19.
[10] Cheng X J, Ye J H. The driving effect of green finance on the sustainable development performance of energy enterprises. Industrial Economic Review (Shandong University), 2024, 23(01): 57-84.
[11] Chen D H. Bank fintech credit decision-making, and the sustainable development of borrowing enterprises. Financial Theory and Practice, 2024(07): 31-46.
[12] Ren X S. Green bond issuance and corporate ESG performance. Contemporary Economic Management, 2024, 46(04): 71-83.
[13] Zhang Y, Liu J Y. Green finance, green technological innovation, and high-quality economic development. Science Technology and Industry, 2025, 25(10): 313-318.
[14] Ren Z R. How does green finance promote the green low-carbon development of the economy?. Financial Development Research, 2025(07): 58-67.
[15] Mao X M, Wang R Z. Green finance and new-quality productive forces: Promotion or inhibition? From the perspective of technological innovation and environmental attention. Journal of Shanghai University of Finance and Economics, 2024, 26(05): 30-45.
[16] Zhang X Y, Guo A J, Lei Z H. Does green finance improve corporate total factor productivity? A quasi-natural experiment based on green finance reform and innovation pilot zones. Journal of University of Jinan (Social Science Edition), 2024, 34(02): 86-100.
[17] Meng W F, Liu J H. The Effect and Heterogeneity of Green Finance Promoting High-Quality Economic Development: From the Perspective of Technological Innovation and Industrial Structure Upgrading. Economic Review, 2023, (07): 100-110.
[18] Zhao Y. Green finance and urban planning: accelerating China's wind energy for environmental sustainability. GeoJournal, 2025, 90(5): 224.
[19] Habib A, Khan A M. Bank financing and green financing: The influence of sustainable practices on investment sensitivity. Sustainable Futures, 2025(10): 100775. DOI: https://doi.org/10.1016/j.sftr.2025.100775.
[20] Yu Y. Green finance as a catalyst for sustainable development: exploring the role of green bonds and impact investment in advancing environmental goals. Journal of Fintech and Business Analysis, 2025, 2(2): 27-31.