

Green Finance and Corporate Carbon Performance

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Abstract. Based on data of Chinese A-share listed enterprises from 2012 to 2023, this study empirically examines the impact of green finance on corporate carbon performance. The findings are as follows. First, green finance significantly improves corporate carbon performance, and the result remains robust after replacing the model with a fixed-effects model and excluding sample enterprises from pilot zones for green finance reform and innovation. Second, mechanism analysis shows that green finance can further enhance corporate carbon performance by strengthening enterprises' green strategic orientation and alleviating their financing constraints. Third, for non-state-owned enterprises, non-heavily polluting enterprises and non-green credit-restricted enterprises, green finance can significantly improve corporate carbon performance, while this effect is not significant for state-owned enterprises, heavily polluting enterprises and green credit-restricted enterprises.

Keywords: Green Finance, Carbon Performance, Green Strategic Orientation, Financing Constraints

1. Introduction

From the perspective of global climate governance, facing increasingly severe climate risks, how to guide microeconomic entities to achieve low-carbon transition through financial instruments has become a core issue of common concern to both academia and policymakers. As the world's largest carbon emitter and an active participant in global climate governance, China clearly put forward the "30·60" dual carbon goals in 2020, marking that carbon emission reduction has been fully transformed from an international commitment into a domestic rigid constraint. In this context, green finance is highly expected for its unique functions in resource allocation, risk management and market incentives.

From the perspective of macro policy, the construction of China's green finance system has moved from top-level design to in-depth practice. Since the release of the *Green Credit Guidelines* in 2012, innovative instruments such as green bonds, carbon emission trading and sustainability-linked bonds have been launched one after another, and pilot zones for green finance reform and innovation have been established successively, with the policy framework becoming increasingly sound. However, the release effect of policy dividends ultimately depends on the substantive transformation of micro enterprise behavior.

From the perspective of micro enterprises, carbon performance, namely enterprises' carbon emission intensity, emission reduction costs and carbon management efficiency, is not only a key

indicator to measure their fulfillment of environmental responsibilities, but also a core yardstick to evaluate the effectiveness of green finance policies. At present, high-carbon industries are faced with the coexistence of "financing difficulties", "high financing costs" and greenwashing risks in the process of low-carbon transition. Whether green finance truly drives the improvement of corporate carbon performance or only stays at the appearance of "words outweigh actions" urgently needs rigorous empirical verification. From the perspective of instrument innovation, differentiated products such as green credit, green bonds and even carbon financial instruments have complex and far-reaching impacts on enterprise carbon emission reduction through multiple paths including financial support, cost internalization and technological innovation incentives.

Although existing studies have carried out useful explorations on the environmental effects of green finance, there is still room for further deepening. Some literatures focus on the macro impact of green finance policies on regional or industrial carbon emissions, and the analysis of the micro mechanism of action on enterprise-level carbon performance is still insufficient. Other studies focus on the financing cost effect of green bond issuance or ESG performance, but fail to fully reveal the transmission chain from "financial support" to "carbon performance improvement". In particular, the mediating mechanisms in terms of enterprises' substantive innovation, resource orchestration and governance constraints need to be clarified. Based on this, this study intends to systematically discuss the following core issues: (1) What impact does green finance development have on corporate carbon performance? (2) Through which mediating paths is this impact realized? (3) What differences exist in the carbon performance improvement effect of green finance among enterprises with different property rights, industry attributes and green credit restriction status? Solving these problems, theoretically, helps to deepen the understanding of the relationship between financial functions and environmental performance, enrich empirical evidence of the micro environmental effects of green finance, and provide new explanatory scenarios for the application of signaling theory and resource orchestration theory in the context of low-carbon transition. Practically, the research conclusions can provide decision-making references for optimizing the design of green finance policies, preventing greenwashing risks, and guiding funds to accurately flow to substantive low-carbon transition activities, so as to support the steady advancement of the "dual carbon" goals.

The marginal contributions of this study are mainly reflected in three aspects. First, it breaks through the limitation of single policy or instrument analysis, constructs a comprehensive analysis framework covering multi-dimensional green finance indicators and corporate carbon performance, and depicts the micro environmental effects of green finance more comprehensively. Second, it deeply investigates the multiple mediating mechanisms and boundary conditions of green finance affecting corporate carbon performance, reveals the "black box" from "financial support" to "performance improvement", and provides new empirical evidence for understanding the action path of green finance. Third, based on the perspective of enterprise heterogeneity, it systematically compares the differences in carbon performance of enterprise groups with different characteristics empowered by green finance, providing a micro basis for targeted policy implementation and differentiated institutional design.

2. Literature review

Regarding relevant studies on green finance and corporate carbon performance, Hao and Wu found that there is a significant U-shaped relationship between green finance and urban carbon emission performance, and green finance forms the above nonlinear relationship by exerting a dynamic effect of first inhibiting and then promoting green technology diffusion and enterprise green management performance [1]. Zhang and Liu found that the carbon performance of enterprises in pilot zones for

green finance reform and innovation is significantly improved, and cost pressure and green innovation play a parallel mediating role in the process of pilot policies affecting enterprise carbon performance [2].

Regarding relevant studies on green finance and enterprise carbon emissions, most studies show that green finance promotes enterprise carbon emission reduction. Huang and Qin found that green finance promotes the reduction of agricultural carbon emissions through two paths: agricultural industrial agglomeration and agricultural technology spillover to a certain extent [3]. Zhang et al. found that the pilot of green finance reform and innovation zones drives downstream carbon emission reduction through neutral technological progress and embodied technological progress. It can be observed that the policy pilot has expanded downstream investment in ecological and environmental protection and improved downstream patent quality [4]. Cheng et al. found that the green finance pilot policy plays a role through the three-wheel drive of "capital + technology + awareness" [5]. Guo and Fang found that the level of green technology innovation has a significant mediating effect, and the mediating effect of industrial structure rationalization has a masking effect [6]. Kang et al. found that green technological progress and ecologicalization of industrial structure play important roles in green finance promoting carbon emission reduction [7]. Wang and Li found that green finance significantly reduces urban carbon emissions in China, and this effect is mainly realized by promoting urban industrial green transformation and improving urban green innovation capacity [8]. Li found that green finance reform can effectively reduce carbon emissions in pilot zones and has a spillover effect of carbon reduction [9]. Zheng et al. found that green finance development in the Yangtze River Delta region curbs carbon emissions by promoting green technology innovation and industrial structure upgrading; in the transmission mechanism of green technology innovation, strategic technological innovation plays a major role [10].

3. Research design

3.1. Model setting

To further investigate the internal relationship between green finance and corporate carbon performance, this study sets the following model:

$$Performance_{it} = \alpha_0 + \beta_0 Green_finance_{it} + \sum \gamma_k Control_{it} + \varepsilon_{it} \quad (1)$$

Where *Performance*, *Green_finance*, *Control* and ε represent corporate carbon performance, green finance, a series of control variables and error term respectively. α_0 represents the constant term, and β_0 and γ_k represent the coefficients of variables respectively.

3.2. Variable definition

For the explained variable, the reciprocal of total carbon emissions per million yuan of net sales is used to measure corporate carbon performance.

For the core explanatory variable, this study constructs a comprehensive evaluation system of green finance and calculates it by the entropy method. For control variables, this study selects a series of control variables from the enterprise level and the macro level respectively, specifically including: (1) Enterprise-level variables: firm size (Size), firm profitability (ROA), firm solvency (Leverage), firm liquidity level (Liquidity), firm age (Age), board size (Board), executive compensation (Salary), ownership concentration (Top5), price-earnings ratio (PE); (2) Macro-level

variables: regional economic development level (GDP), regional industrial structure status (Industry), regional financial development level (Finance).

Table 1. Comprehensive evaluation system of green finance

Dimension	Indicator	Calculation Method
Green Credit	Proportion of loans for environmental protection projects	Total loans for environmental protection projects in the province / Total loans of the province
Green Investment	Proportion of investment in environmental pollution control to GDP	Investment in environmental pollution control / GDP
Green Insurance	Popularization degree of environmental pollution liability insurance	Income from environmental pollution liability insurance / Total premium income
Green Bonds	Development degree of green bonds	Total issuance of green bonds / Total issuance of all bonds
Green Support	Proportion of fiscal expenditure on environmental protection	Fiscal expenditure on environmental protection / General fiscal budget expenditure
Green Funds	Proportion of green funds	Total market value of green funds / Total market value of all funds
Green Equity	Development depth of green equity	Carbon trading, energy use right trading, pollutant discharge right trading / Equity market transactions

3.3. Data source and descriptive statistics

This paper selects Shanghai and Shenzhen A-share listed companies from 2012 to 2023 as research samples, and carries out the following processing: First, exclude enterprises marked as ST, *ST, PT, suspended from listing, terminated from listing, as well as companies in the financial industry; second, exclude samples with a large amount of missing data; third, match and integrate the data of each variable. In terms of data sources, green finance data come from *China Energy Statistical Yearbook*, *China Science and Technology Statistical Yearbook* and *China Financial Yearbook*, other enterprise-level data come from the CSMAR Database, and macro-level data come from the Wind Database. The descriptive statistics of each variable are shown in Table 2.

Table 2. Descriptive statistics of variables

VarName	Obs	Mean	SD	Min	Max
Performance	17914	0.751	0.876	0.255	3.811
Green_finance	24451	0.412	0.100	0.116	0.632
Size	25486	3.093	0.058	2.987	3.241
ROA	25485	0.052	0.061	-0.154	0.171
Leverage	22908	1.148	0.428	0.640	3.238
Liquidity	25457	0.780	2.047	-5.723	8.204
Board	17692	8.297	1.530	5.000	12.000
Salary	17644	0.312	0.376	0.006	1.689
Age	25483	9.213	8.380	0.000	27.000
PE	21658	56.347	74.514	6.843	408.667
Top5	25241	0.483	0.185	0.220	0.905

Table 2.(continued)

Industry	25691	55.527	10.445	41.100	83.700
GDP	25691	10.790	0.695	8.901	11.818
Finance	25691	1.703	0.435	0.956	2.631

4. Empirical analysis

4.1. Basic regression analysis

The basic regression results are shown in Table 3. It can be seen that with the addition of control variables at the enterprise financial level, enterprise governance level and macroeconomic level, the regression coefficient of green finance (Green_finance) is always significantly positive, indicating that green finance significantly improves corporate carbon performance.

Table 3. Basic regression results

VARIABLES	(1) Performance	(2) Performance	(3) Performance	(4) Performance
Green_finance	2.8189*** (32.33)	2.4695*** (28.25)	2.5045*** (24.30)	1.1081*** (8.09)
Size		2.4949*** (16.78)	2.3814*** (10.48)	1.9743*** (8.88)
ROA		-2.2867*** (-11.56)	-1.2697*** (-5.31)	-0.8027*** (-3.62)
Leverage		-0.2124*** (-11.49)	-0.2130*** (-9.23)	-0.1414*** (-6.66)
Liquidity		0.0206*** (5.60)	0.0255*** (6.05)	0.0177*** (4.68)
Board			-0.0420*** (-6.59)	-0.0152** (-2.51)
Salary			0.2307*** (6.72)	0.1866*** (5.70)
Age			0.0183*** (12.94)	0.0170*** (12.28)
PE			0.0001 (0.93)	0.0002* (1.80)
Top5			-0.1622*** (-3.03)	-0.0236 (-0.46)
Industry				-0.0394*** (-28.13)
GDP				0.2781*** (16.24)
Finance				1.3263***

Table 3. (continued)

				(48.48)
Constant	-0.3905***	-7.6376***	-7.2467***	-8.8665***
	(-10.50)	(-16.59)	(-10.40)	(-12.91)
Number of samples	17,910	16,261	11,485	11,485
Number of enterprises	3,241	3,212	2,244	2,244

Note: z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.2. Robustness analysis

This study carries out the following robustness tests. First, the fixed-effects model is used. The regression results are shown in column (1) of Table 4. It can be seen that the regression coefficient of green finance (Green_finance) is always significantly positive, which still indicates that green finance promotes the improvement of corporate carbon performance. Second, sample enterprises from pilot zones for green finance reform and innovation are excluded. The regression results are shown in column (2) of Table 4. It can be seen that the regression coefficient of green finance (Green_finance) is still significantly positive, which once again indicates that green finance promotes the improvement of corporate carbon performance.

Table 4. Robustness test results

VARIABLES	(1) Using fixed-effects model	(2) Excluding sample enterprises from pilot zones for green finance reform and innovation
Green_finance	4.9567*** (7.88)	1.0548*** (7.46)
Size	-1.1565** (-2.46)	1.9428*** (8.24)
ROA	-0.7221*** (-2.77)	-0.7576*** (-3.14)
Leverage	-0.1130*** (-4.75)	-0.1370*** (-5.95)
Liquidity	0.0138*** (3.77)	0.0181*** (4.46)
Board	-0.0040 (-0.45)	-0.0116* (-1.78)
Salary	-0.1316*** (-2.63)	0.1627*** (4.72)
Age	0.2007*** (19.95)	0.0155*** (10.60)
PE	-0.0000 (-0.09)	0.0002* (1.70)
Top5	0.3745***	-0.0038

Table 4. (continued)

	(4.37)	(-0.07)
Industry	-0.1239***	-0.0389***
	(-36.05)	(-26.69)
GDP	-1.2073***	0.2966***
	(-13.04)	(16.53)
Finance	1.6675***	1.3479***
	(32.03)	(44.19)
Constant	17.3934***	-9.0220***
	(10.30)	(-12.39)
Number of samples	11,485	9,730
Number of enterprises	2,244	1,955

Note: z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.3. Mechanism analysis

Furthermore, this study investigates the impact mechanism of green finance on corporate carbon performance from the perspectives of enterprise green strategic orientation (GSO) and enterprise financing constraints (SA_index) respectively.

Among them, for green strategic orientation (GSO), referring to the practice of existing studies [11], this study uses the sum of 7 indicators extracted from the annual reports and social responsibility reports of listed enterprises to measure: whether the enterprise has environmental protection concepts, whether it has environmental protection goals, whether it has an environmental protection management system, whether it has passed ISO 14000, whether it carries out environmental protection education and training, whether it carries out special environmental protection activities, and whether it implements the "Three Simultaneities" system. For enterprise financing constraints (SA_index), this study calculates it with reference to the practice of existing studies [12].

The regression results are shown in Table 5. Columns (1) to (2) show that green finance can further positively affect corporate carbon performance by positively affecting enterprise green strategic orientation. Columns (3) to (4) show that green finance can further improve corporate carbon performance by alleviating enterprise financing constraints.

Table 5. Mechanism test results

VARIABLES	(1) GSO	(2) Performance	(3) SA_index	(4) Performance
Green_finance	0.5571*	1.1238***	-0.4653***	1.0352***
	(1.86)	(8.41)	(-13.69)	(7.62)
GSO		0.0974***		
		(21.43)		
SA_index				-0.4190***

Table 5. (continued)

				(-10.33)
Size	12.5334***	0.6905***	-0.0482	2.5606***
	(28.28)	(3.07)	(-1.50)	(11.25)
ROA	1.1508***	-0.9622***	0.0818***	-0.7897***
	(2.98)	(-4.43)	(4.10)	(-3.58)
Leverage	-0.1281***	-0.1315***	-0.0058***	-0.1506***
	(-3.62)	(-6.32)	(-3.25)	(-7.12)
Liquidity	-0.0057	0.0171***	-0.0003	0.0173***
	(-1.03)	(4.61)	(-1.06)	(4.58)
Board	0.0121	-0.0194***	0.0035***	-0.0159***
	(1.08)	(-3.27)	(5.27)	(-2.64)
Salary	0.1151**	0.1677***	0.0414***	0.2072***
	(2.06)	(5.24)	(12.37)	(6.36)
Age	0.0159***	0.0155***	-0.0230***	0.0081***
	(5.58)	(11.47)	(-64.25)	(5.07)
PE	0.0004*	0.0002	0.0001***	0.0003***
	(1.96)	(1.59)	(7.38)	(2.62)
Top5	0.1192	-0.0335	-0.0444***	-0.0089
	(1.22)	(-0.67)	(-7.25)	(-0.17)
Industry	-0.0297***	-0.0369***	0.0005**	-0.0375***
	(-11.04)	(-26.95)	(2.35)	(-26.85)
GDP	0.3813***	0.2426***	-0.0674***	0.2463***
	(10.42)	(14.45)	(-15.60)	(14.28)
Finance	0.9999***	1.2317***	-0.0499***	1.2631***
	(18.63)	(45.51)	(-13.72)	(45.55)
Constant	-41.8952***	-4.5979***	-2.5318***	-11.8417***
	(-30.87)	(-6.57)	(-24.81)	(-16.01)
Number of samples	14,993	11,485	14,993	11,485
Number of enterprises	3,092	2,244	3,092	2,244

Note: z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.4. Heterogeneity analysis

The heterogeneity test results are shown in Table 6. It can be seen that for non-state-owned enterprises, green finance can significantly improve corporate carbon performance, while for state-owned enterprises, this effect is not significant. For non-heavily polluting enterprises, green finance can significantly improve corporate carbon performance, while for heavily polluting enterprises, this effect is not significant. For non-green credit-restricted enterprises, green finance can significantly improve corporate carbon performance, while for green credit-restricted enterprises, this effect is not significant.

Table 6. Heterogeneity test results

VARIABLES	(1) State-owned enterprises	(2)	(3) Non-state-owned enterprises	(4) Heavily polluting enterprises	(5) Non-heavily polluting enterprises	(6) Green credit- restricted enterprises
Green_financ e	0.2814 (1.36)	0.6823*** (5.05)	0.1291 (0.68)	1.7025*** (9.47)	-0.7376 (-1.37)	1.4578*** (9.05)
Size	1.3168*** (3.62)	1.8248*** (8.07)	2.2777*** (6.78)	1.7105*** (6.05)	3.0711** (2.44)	1.9986*** (7.74)
ROA	-0.2782 (-0.67)	-0.1464 (-0.69)	-1.1622*** (-3.38)	-0.6583** (-2.30)	1.8253 (1.28)	-0.7716*** (-3.19)
Leverage	-0.0842** (-2.53)	-0.1398*** (-6.11)	-0.1323*** (-4.01)	-0.1668*** (-6.06)	-0.1419 (-1.13)	-0.1284*** (-5.73)
Liquidity	-0.0076 (-1.20)	0.0218*** (5.47)	0.0060 (0.89)	0.0212*** (4.62)	-0.0263 (-0.75)	0.0214*** (5.42)
Board	-0.0165 (-1.61)	-0.0086 (-1.43)	-0.0053 (-0.54)	-0.0187** (-2.49)	0.0219 (0.81)	-0.0197*** (-2.87)
Salary	-0.0535 (-0.62)	0.1581*** (5.32)	0.2468*** (4.16)	0.1554*** (3.95)	0.8156* (1.72)	0.2217*** (5.79)
Age	0.0127*** (5.69)	0.0127*** (8.58)	0.0140*** (6.96)	0.0171*** (9.64)	0.0144** (2.24)	0.0182*** (11.23)
PE	0.0002 (1.00)	0.0002 (1.24)	0.0005** (2.30)	0.0001 (0.78)	-0.0006 (-0.62)	0.0002 (1.49)
Top5	-0.0304 (-0.37)	0.0257 (0.50)	-0.0067 (-0.09)	-0.0196 (-0.30)	-0.2766 (-1.12)	-0.0299 (-0.52)
Industry	-0.0384*** (-17.04)	-0.0242*** (-17.25)	-0.0318*** (-13.94)	-0.0422*** (-24.40)	-0.0315*** (-5.94)	-0.0445*** (-26.93)
GDP	0.3250*** (11.28)	0.1852*** (11.44)	0.2871*** (11.19)	0.2592*** (11.98)	0.1992** (2.27)	0.2763*** (13.90)
Finance	1.2909*** (23.88)	0.8756*** (33.29)	1.0694*** (25.77)	1.4139*** (40.83)	1.2240*** (6.96)	1.4456*** (46.76)
Constant	-7.0093***	-7.4580***	-9.5683***	-8.0351***	-11.3748***	-8.9831***

Table 6. (continued)

	(-6.17)	(-10.68)	(-9.30)	(-9.17)	(-2.87)	(-11.29)
Number of samples	2,922	7,700	3,566	7,919	342	10,076
Number of enterprises	586	1,701	705	1,600	65	2,051

Note: z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

5. Conclusion

Based on data of Chinese A-share listed enterprises from 2012 to 2023, this study empirically examines the impact of green finance on corporate carbon performance. The findings are as follows. First, green finance significantly improves corporate carbon performance, and the result remains robust after replacing the model with a fixed-effects model and excluding sample enterprises from pilot zones for green finance reform and innovation. Second, mechanism analysis shows that green finance can further enhance corporate carbon performance by strengthening enterprises' green strategic orientation and alleviating their financing constraints. Third, for non-state-owned enterprises, non-heavily polluting enterprises and non-green credit-restricted enterprises, green finance can significantly improve corporate carbon performance, while this effect is not significant for state-owned enterprises, heavily polluting enterprises and green credit-restricted enterprises.

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