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Green Finance and Green Innovation Output in Chinese Manufacturing Enterprises: Evidence from A-share Listed Firms, 2010-2024

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Abstract

Purpose – This paper examines the impact of green finance on green innovation output in Chinese manufacturing firms. It also explores the mechanisms, firm-level differences, and moderating factors in this relationship.

Design/Methodology/Approach – The study uses panel data from Chinese A-share listed manufacturing firms between 2010 and 2024. It applies fixed-effects models, instrumental-variable estimation, robustness tests, and mechanism, heterogeneity, and moderation analyses.

Findings – Green finance significantly promotes corporate green innovation by increasing R&D investment, environmental pressure, and green transformation. The effect is stronger in highly competitive, growing or declining, and digitally advanced firms, and is reinforced by ESG performance and collaborative green patents.

Research Implications – Policymakers should improve green finance systems and provide more targeted support across regions and firms. Financial institutions should also consider ESG performance and collaborative innovation when allocating green financial resources.

Keywords: green finance; green innovation; manufacturing firms; R&D investment

JEL Classifications: G21, O31, Q55, G32

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I. Introduction

China's dual-carbon strategy has made the green transformation of manufacturing a core part of high-quality economic development. Manufacturing is still a relatively high-energy-consumption and carbon-emitting industry, but at the same time, new technologies can be introduced to reduce both environmental pollution and energy waste significantly. Green technological innovation is relatively costly and uncertain, but has positive externalities. In the past, financial markets have been unable to raise funds for such projects because of information asymmetry among investors, a long payback period and the difficulty of monetizing environmental benefits. Therefore, green finance will direct funds towards environmentally friendly projects and away from high-polluting industries.

Research on green credit policies, green bonds, environmental regulations and corporate innovation has been conducted, but little attention has been paid to an all-encompassing green finance index and its firm-level effects in manufacturing(Qian Liu, Yuanji Zhang, Xiaoqing Sun, 2025). his paper addresses three questions.First, has the development of green finance promoted green innovation by manufacturing enterprises? Second, through which mechanisms does it work? Third, in what firm and market conditions is the effect more pronounced? Using city-level green finance indicators and firm-level panel data, this paper provides empirical support for investigating the effect of greening in the financial system on corporate innovation.

II. Theoretical background

The theoretical basis for the above analysis is the theory of sustainable development, signalling theory, Porter's hypothesis and externality theory. Sustainable development theory believes that financial resources should support growth that is in line with resource conservation and pollution reduction. Based on signalling theory, green innovation and ESG performance reduce information asymmetry by providing high-quality information for financial institutions and investors over an extended period. According to Porter's theory, a favourable environment will reduce the cost of conforming to some extent and thus promote innovation. According to the theory of externalities, public policies and green finance are required to internalise the social costs of environmental pollution from green innovation(Liu, Q., Guo, Q., & Umair, M., 2026).

Green Finance can promote green innovation in the following ways. First, it will ease financing pressure and reduce the cost of capital for green R&D. Secondly, regulators and the market will likely raise the company's risk awareness through relevant regulations or information disclosures(Qian Liu, 2025). Thirdly, it promotes the green transformation of the company by incorporating green concepts into strategy, production and disclosure. The effect may vary across firms. Firms in more competitive markets need to raise funds for technological upgrading more urgently. Firms at different stages in their life cycles also have different risk appetites and resource allocations. Digitalisation can enhance the efficiency of information processing and production

optimisation to provide support for the green-tech upgrading effort.

III. Data, variables and model

The sample is Chinese A-share listed manufacturing enterprises from 2010 to 2024. Green patent data are obtained from the CNRDS green patent database; financial and governance variables are taken from CSMAR and Wind; city-level green finance indicators are calculated based on statistical yearbooks; ESG ratings are provided by the Huazheng ESG database; and annual report text data are obtained from CNRDS. After matching and cleaning, the main fixed-effects regressions use as many as 38,797 firm-year observations, and the exact sample varies among specifications due to missing mechanisms, ESG and patent-collaboration variables.

The dependent variable is green innovation output (GI), and it is represented by ln(green invention patent applications + green utility model patent applications + 1). The core independent variable is the green finance development index (GF). A fixed-base range entropy-weight method is used to build the index, and year-to-year changes in weight are thus avoided for better intertemporal comparison. Control variables are firm size, capital expenditure, board size, institutional ownership, executive compensation, CEO-chairman duality and ownership concentration. The baseline model is: GI_it = alpha + beta GF_ct + gamma Controls_it + Firm_i + Year_t + Industry_j + epsilon_it, where i denotes firm, c city, t year and j industry. A positive and significant beta indicates that the development of green finance is positively associated with the output of green innovation.

Table 1. Green Finance Development Index

Dimension	Indicator	Measurement	Direction
Green credit	Environmental project loans	Environmental project loans / total loans	Positive
Green credit	Loans to six high-energy-consuming industries	Loans to six high-energy-consuming industries / total loans	Negative
Green insurance	Environmental pollution liability insurance	Environmental liability insurance income / total premium income	Positive
Green bonds	Green bond issuance	Green bond issuance / total bond issuance	Positive
Green funds	Green fund market value	Green fund market value / total fund market value	Positive
Green securities	Market value of environmental firms	Environmental firms' market value / A-share market value	Positive
Green securities	Market value of six high-energy-consuming industries	Market value of six high-energy-consuming industries / A-share market value	Negative

Source: Condensed from the original empirical paper. The city-level index is computed according to the fixed-base range entropy-weight method.

Table 2. Descriptive Statistics

Variable	Symbol	Mean	SD	Min	Max
Green innovation output	GI	0.741	1.052	0.000	4.779
Green finance development	GF	0.134	0.029	0.032	0.219
Firm size	Size	22.196	1.345	14.942	28.791
Capital expenditure	Capex	0.046	0.050	-0.475	0.642
Board size	Board	2.110	0.202	1.386	2.890
Institutional ownership	Inst	0.429	0.251	0.000	1.011
Top management pay	TMTPay1	14.664	0.799	0.000	18.292
CEO-chairman duality	Dual	0.309	0.462	0.000	1.000
Ownership concentration	Top1	0.338	0.151	0.011	0.900

The mean VIF is 1.27;Indicating that multicollinearity is not a serious concern

IV. Empirical results

Based on the above data, both green finance and green innovation increased from 2010 to 2024, but at different rates in different areas. Green finance development improved in all four areas, the eastern area was the highest, the central area increased at a faster pace, and the western and northeastern areas performed poorly. Dagum Gini decomposition shows that the overall regional inequality has decreased from 0.259 in 2010 to 0.199 in 2024; however, the density of transvariation remains a primary cause of this reduction. Green innovation output also increased over time, and this increase had a bimodal distribution: most firms remained in the low-output group, and only a small number formed the high-output group.

Table 3 is the baseline result. GF is a positive predictor in the pooled model without fixed effects. Add the fixed effects of firm, year and industry, and then the coefficient is positive and significant. In the preferred specification with controls and fixed effects, the coefficient of GF is 0.909 and statistically significant at the 1% level. Therefore, green finance development is expected to promote an increase in green innovation outputs for manufacturing enterprises.

Table 3. Baseline Regression Results

Variable	(1) GI	(2) GI	(3) GI
GF	4.405***	1.057***	0.909***
	(0.167)	(0.370)	(0.347)
Controls	YES	NO	YES
Firm fixed effects	NO	YES	YES
Year fixed effects	NO	YES	YES
Industry fixed effects	NO	YES	YES
N	39,105	39,924	38,797
R2	0.219	0.707	0.719

Standard errors are shown in parentheses; * denotes 10% significance, ** denotes 5% significance, and *** denotes 1% significance.

Lagged green finance (LGF) is employed as the instrument for endogeneity correction. The first-stage coefficient is 0.687 and is significant at the 1% level; the Kleibergen-Paap LM statistic rejects under-identification, and the Wald F statistic exceeds the weak-instrument threshold. In the second stage, the coefficient of GF is 1.704 and is still significant at the 1% level. Robustness tests also support this result when replacing the dependent variable, adjusting the sample period, adding province fixed effects, and using a reduced sample.

Table 4. Endogeneity and Robustness Tests

Panel / Variable	IV first stage GF	IV second stage GI	Robust 1 GI1	Robust 2 GI	Robust 3 GI	Robust 4 GI
LGF	0.687***					
	(0.009)					
GF		1.704***	0.835***	1.097***	0.782**	1.087**
		(0.615)	(0.321)	(0.355)	(0.343)	(0.474)
Controls	YES	YES	YES	YES	YES	YES
Firm, year, industry FE	YES	YES	YES	YES	YES	YES
Province FE	NO	NO	NO	NO	YES	NO
N	34,237	34,237	38,797	29,856	38,797	20,724
R2	0.929	0.046	0.672	0.694	0.721	0.705

The IV model uses lagged green finance. KP rk LM = 679.393, p = 0.0000; KP rk Wald F = 5986.884.

Mechanism tests examine the three mediation paths influenced by green finance. As shown in Table 5, GF has raised the intensity of R&D investment, environmental regulatory pressure and corporate green transformation. The coefficients are 0.566, 4.780 and 0.622. Based on the above analysis, green finance appears to be a transmission channel that reduces financing constraints for environmentally friendly projects, increases external pressure on enterprises, and thus drives green innovation.

Table 5. Mechanism Tests

Variable	R&D investment intensity	Environmental regulation pressure	Corporate green transformation
GF	0.566***	4.780***	0.622**
	(0.216)	(1.835)	(0.317)
Controls	YES	YES	YES
Firm fixed effects	YES	YES	YES
Year fixed effects	YES	YES	YES
Industry fixed effects	YES	YES	YES
N	36,898	6,904	38,795
R2	0.751	0.425	0.691

The corporate green transformation variable is based on text analysis of 113 green transformation keywords in the annual report.

The results of heterogeneity in Table 6 show that green finance is not uniformly effective for all enterprises. The effect is significant in high-competition industries but insignificant in low-competition industries. It is also significant for firms in the growth and decline stages, but not for mature firms. In addition, the effect is concentrated among firms with higher digital transformation. Based on the above results, it can be inferred that financial support is more likely to be employed for green innovation by enterprises under significant market pressure, strategic renovation requirements or enhanced use of external resources through digitalisation.

Table 6. Heterogeneity Analysis

Group	High competition	Low competition	Growth stage	Mature stage	Decline stage	High digitalization	Low digitalization
GF	1.027**	0.680	1.149**	0.674	1.172*	1.037***	0.485
	(0.493)	(0.462)	(0.571)	(0.486)	(0.685)	(0.385)	(0.564)
Controls and FE	YES	YES	YES	YES	YES	YES	YES
N	19,166	19,144	13,375	16,081	6,759	27,102	10,875
R2	0.742	0.730	0.745	0.714	0.713	0.700	0.793

All specifications include controls, firm fixed effects, year fixed effects and industry fixed effects.

Moderation analysis shows that ESG ratings and green collaborative invention patents strengthen the effect of green finance. As shown in Table 7, the interaction term of GF and ESG is 0.581 and statistically significant at the 1% level. Therefore, at companies with high ESG performance will be able to raise green finance more easily due to higher disclosure quality, governance capacity and market confidence. The interaction term of GF and green collaborative invention patents is 2.303. It is also statistically significant at the 1% level. Collaborative green invention refers to the sharing of knowledge and resources among organisations to expand the innovative effect of green finance.

Table 7. Moderating Effects of ESG and Green Collaborative Invention Patents

Variable	ESG model (1)	ESG model (2)	ESG model (3)	Patent model (1)	Patent model (2)	Patent model (3)
GF	0.909***	0.861**	0.914***	0.909***	0.845**	1.398***
	(0.347)	(0.349)	(0.349)	(0.347)	(0.334)	(0.356)
ESG		0.033***	0.031***			
lnG					0.338***	0.329***
GF x ESG			0.581***			
GF x lnG						2.303***
Controls and FE	YES	YES	YES	YES	YES	YES
N	4,125	4,123	4,123	38,797	38,797	38,797
R2	0.719	0.721	0.721	0.719	0.730	0.731

ESG ratings range from 1 to 9, and lnG is defined as the natural logarithm of green collaborative invention patent applications plus 1.

V. Discussion and policy implications

Based on the above results, green finance should be regarded as a form of governance and signal, rather than merely a way of financing. Provide funds for green projects to reduce the cost of environmentally friendly research and development and increase the expected return on investment in green innovation via green finance. Environmental performance in lending and investment decisions will also increase the perceived regulatory risk for the company and drive green transformation from within.

The three are the following policies. First, the regulator should continue to promote the development of green finance for industrial upgrading and strengthen standards for green credit, bonds, insurance, funds and securities. Second, the regional policies are not uniform. The eastern Area will focus on high-quality green financial products and innovation-driven upgrading; the central, western and northeastern Areas need stronger institutional capacity, information infrastructure and project pipelines. Thirdly, the financial institution can add ESG disclosure and cooperative innovation indicators to the green finance evaluation system. Companies with good ESG governance and cooperative patent activities will be better able to achieve the goals of green innovation supported by the funds. Therefore, according to the above results, the company needs to obtain

green funds first. The company needs good self-transformation capabilities, will invest in R&D, adopt digital tools and build organisational routines to implement the green transformation strategy in production. Otherwise, green finance will only support superficial compliance without technological innovation.

VI. Conclusion

Data in this paper show that the development of green finance has increased the output of green innovation for Chinese manufacturing enterprises. After controlling for firm, year and industry fixed effects, the results are still stable; instrument-variable estimation and multiple robustness tests have also been carried out. Mechanism experiments have shown that this is achieved by an increase in high-intensity R&D investment, stricter environmental regulations, and corporate green transformation. Analysis of heterogeneity shows that the effect is relatively larger for firms in highly competitive industries, those that are growing or declining, and digitally advanced firms. ESG ratings and green collaborative invention patents have added to this extent.

The study adds to the body of research by connecting a multi-dimensional green finance index with firm-level green patent output in manufacturing. The quantity of patents may not fully reflect the quality of green innovation. In the future, research may add patent citations, commercialisation results, carbon reduction performance and cross-country comparisons to determine whether green finance promotes deep technological change or only an increase in patent applications.

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