Research On the Impact of Green Finance on Enterprise Innovation

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Abstract. With the rapid development of China's economy, the unique high input and high consumption of the extensive growth model has brought great negative impacts on the environment. China has begun to explore sustainable and high-quality development models, and how to effectively promote enterprise innovation and improve enterprise innovation capabilities has become an urgent problem that needs to be solved. This article selects manufacturing companies in the Chinese A-share market from 2012 to 2021 as research samples and uses a fixed effects model to study the relationship between green finance and enterprise innovation. The results show that green finance can effectively alleviate the problem of enterprise funding shortage, support enterprise innovation, and improve innovation output. Finally, this article proposes corresponding policy recommendations to encourage the country to continuously play the important role of green finance in deepening China's economic reform.

Keywords: Green finance; Enterprise innovation; Economic development.

1. Introduction

In the 2022 Chinese government report, it was pointed out that China will continue to "strengthen ecological and environmental protection, promote sustainable development", "launch a national carbon emission trading market", and "orderly promote carbon peak neutrality work". In exploring the path of green and sustainable development of China's economy, green finance has been widely applied due to its unique advantages. Green finance is an important tool for promoting the improvement of enterprise innovation capabilities. The establishment of the strategic goals of carbon neutrality and carbon peaking promotes green finance to move from virtual to practical, effectively serving the real economy, guiding Chinese enterprises to open up high-quality development paths through capital flow, continuously increasing R&D investment, improving R&D output, and improving innovation performance. Technological innovation brings green transformation ideas to enterprises and China's national economic system by improving traditional technological means of high input and low output, reducing energy consumption, improving production efficiency.

2. Literature review

The concept of green finance has been studied and discussed by scholars. You Yi (2022) believes that green finance is a transitional finance that uses policy rules to guide finance towards energy conservation, emission reduction, environmental protection, and efficiency, and is adapted to policy guidance. China should learn from advanced development concepts from foreign countries, combine with China's actual situation, carry out Sino foreign cooperation research on green finance, and jointly promote the development of green finance in China.

In terms of enterprise innovation, this article mainly explores the innovation issues of enterprises in patent technology. Enterprise technological innovation is an important factor that affects the future sustainable development of enterprises. At the same time, innovation can also serve as a bridge between green and innovation, helping enterprises achieve a balance between economic development and environmental protection.

Regarding the research on the relationship between green finance and enterprise innovation, Lin Muxi and Xiao Yubo (2023) believe that green finance utilizes its unique financial advantages to gather high-quality resources, help enterprises generate green industry scale effects, and then produce intangible assets such as brands, technologies, and innovation patents.

3. Research Design

3.1. Research Assumptions

3.1.1 Green finance development and enterprise innovation

Technological innovation is a long-term and high investment research and development activity, which carries great risks. The sustainability and risk of innovation mean that enterprise research and development highly relies on capital investment, and relying solely on the internal capital stock of the enterprise cannot meet the requirements of innovation. Therefore, external financial support is particularly important in stimulating enterprise innovation and improving innovation efficiency. Green finance helps reduce the entry threshold for corporate financing, meets the financing needs of more enterprises, and creates possibilities for improving their innovation capabilities. Based on this, this article proposes the hypothesis:

H1: Green finance has a significant positive promoting effect on enterprise innovation.

3.1.2 Efficient and inefficient innovation

Green finance has to some extent alleviated the shortage of research and development funds. Efficient innovation requires more investment in research and development costs. Correspondingly, the increase in intangible assets generated by efficient innovation and the expected return rate of projects are much higher than those of inefficient innovation. Due to the increase in investment return rate, enterprises are more willing to invest the green funds obtained in efficient innovation projects, thereby improving the output of efficient innovation; Inefficient innovation does not have strong appeal. Based on this, this article proposes the hypothesis:

H2: Green finance has a significant positive promoting effect on both efficient and inefficient innovation of enterprises, but its driving effect on efficient innovation is greater than that on inefficient innovation.

3.1.3 Economically developed and underdeveloped regions

The level of economic development is closely related to the level of green finance development and the innovation ability of local enterprises. In studying the relationship between green finance and enterprise innovation, the level of regional economic development is included in the research scope. The development level of green finance in economically developed regions is higher, and the impact of green finance on enterprise innovation is more significant. Based on this, the standard proposes the hypothesis:

H3: Green finance has a more significant positive promoting effect on enterprises in economically developed regions.

3.2. Model design

3.2.1 Data source

This article selects manufacturing companies in the Chinese A-share market from 2012 to 2021 as the research sample, excluding ST, ST *, and companies with severe data deficiencies, resulting in a total of 1018 manufacturing companies. The data in this article mainly falls into the following three categories: 1.Enterprise innovation data, mainly sourced from CNRDS databases; 2.Green finance data mainly comes from "China Industrial Statistical Yearbook", "Economic Census Yearbook", etc; 3.Enterprise financial data mainly comes from the CSMAR database. This article performed a 1% tail reduction on the selected variables, resulting in 10180 samples.

3.2.2 Model construction

Referring to the practices of Wu Chengsong (2023) and You Minglei (2022), a model (1) is constructed to test the impact of green finance development on enterprise innovation:

$$Innoi,t=C0+\alpha0*gfi,t+\beta0*Control+\varepsilon i,t \quad (1)$$

Inno represents enterprise innovation. Considering that the number of applications for certain years is 0, the logarithm of the number of enterprise patent applications plus 1 is used as the measurement indicator. GF represents the level of green finance development in the location where the enterprise is located. Referring to Jia Tingting's (2022) research, the interest ratio of the top six high energy consuming industries is used as a measurement indicator. Control represents the control variable; ε is a random perturbation term; i represents the target research company; t represents the year.

Referring to the practices of Wu Chengsong (2023) and You Minglei (2022), models (2) and (3) are constructed to conduct regression analysis on efficient and inefficient innovation of enterprises, and further explore the relationship between green finance and innovation quality:

$$InnoH_{i,t}=C_1+\alpha_1*gf_{i,t}+\beta_1*Control+\varepsilon_{i,t} \quad (2)$$

$$InnoL_{i,t}=C_2+\alpha_2*gf_{i,t}+\beta_2*Control+\varepsilon_{i,t} \quad (3)$$

InnoH stands for efficient innovation; InnoL stands for inefficient innovation.

3.2.3 Variable selection

The dependent variable is enterprise innovation. The explanatory variable is green finance. The main control variables are the various financial indicators of the enterprise itself. Specific measurement indicators are shown in Table 1.

Table 1 Variable Measurement Indicators

Types	Variables	Meanings	Measuring method
Explained Variables	Inno	Enterprise Innovation	Ln(1+ total number of enterprise patent applications)
	InnoH	Efficient innovation	Ln(1+ number of invention patent applications+number of utility model patent applications)
	InnoL	Inefficient innovation	Ln(1+ number of design patent applications)
Explanatory variable	Gf	green finance	1- Interest expenses for six high energy consuming industries
Control variables	Gro	Enterprise Growth Capability	Total Assets Growth Rate
	Ope	Enterprise Business Capability	Inventory turnover rate
	Str	Corporate governance structure	Number of independent directors/board of directors
	ROA	Corporate profitability	Net profit/total asset balance

4. Empirical analysis

4.1. Descriptive Statistics

The descriptive statistical results of Table 2 show that in manufacturing enterprises, the average innovation level is 3.398 units, the average efficient innovation level is 3.265 units, and the average

inefficient innovation level is 0.966 units. From the above data, it can be seen that enterprises pay more attention to efficient innovation, as the technological breakthroughs brought about by efficient innovation can help enterprises gain more competitive advantages, resulting in more output from efficient innovation. The average green finance received by enterprises is 0.584, with a maximum value of 0.753 and a minimum value of 0.207. Different enterprises receive different levels of green finance support, and there is still a significant gap.

Table 2 Decriptive statistics

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
code	10,180	239,630	259,623	21	603,766
year	10,180	2,017	2.872	2,012	2,021
Ino	10,180	3.398	1.515	0	7.112
InnoH	10,180	3.265	1.530	0	7.037
InnoL	10,180	0.966	1.327	0	5.094
gf	10,180	0.584	0.117	0.207	0.753
gro	10,180	0.132	0.221	-0.248	1.229
ope	10,180	4.354	3.705	0.448	22.38
str	10,180	0.375	0.0539	0.333	0.571
ROA	10,180	0.0405	0.0537	-0.172	0.196
lnRD	10,180	18.26	1.342	14.86	21.89
lev	10,180	0.394	0.181	0.0533	0.794
led	10,180	0.868	0.339	0	1

4.2. Regression result analysis

This article uses StataMP17 for fixed effects regression estimation, and Table 3 shows the regression results of model (1).

Table 3 Basic Regression

	(1)	(2)
	Inno	Inno
gf	2.054***	2.029***
	(0.317)	(0.316)
gro		-0.0871
		(0.0535)
ope		-0.00397
		(0.00852)
str		-0.385
		(0.394)
ROA		-0.494
		(0.319)
_cons	2.198***	2.406***
	(0.185)	(0.227)
N	10180	10180
R^2	0.693	0.694
adj. R^2	0.659	0.659

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3 shows the regression results of model (1). From the regression result (2), it can be seen that green finance is significant at the 1% level, with a variable coefficient of 2.029. This means that for every unit increase in the development level of green finance, the innovation level of enterprises will increase by 2.029 units. This indicates that the development of green finance has a significant promoting effect on enterprise innovation, which verifies hypothesis 1.

Next, enterprise innovation will be divided into efficient innovation and inefficient innovation, and regression analysis will be conducted separately. The regression results are shown in Table 4.

For efficient innovation, green finance is significant at the 1% level and has strong significance. The variable coefficient is 2.135, indicating that for every unit increase in the development level of green finance, the efficient innovation level of enterprises increases by 2.135 units. For inefficient innovation, green finance is significant at the 1% level, with a variable coefficient of 0.724, indicating that for every unit increase in the development level of green finance, enterprise inefficient innovation will increase by 0.724 units. Efficient innovation benefits more from the development of green finance, while the research and development level of design patents in inefficient innovation is significantly affected by green finance, but overall, its effectiveness is inferior to efficient innovation.

Table 4 Efficient and Inefficient Innovation

	(1)	(2)
	InnoH	InnoL
gf	2.135***	0.724***
	(0.323)	(0.235)
gro	-0.0957*	-0.0175
	(0.0542)	(0.0438)
ope	-0.00529	-0.00757
	(0.00855)	(0.00548)
str	-0.300	-0.235
	(0.397)	(0.293)
ROA	-0.405	-0.999***
	(0.319)	(0.220)
_cons	2.183***	0.707***
	(0.233)	(0.170)
N	10180	10180
R^2	0.693	0.721
adj. R^2	0.659	0.690

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Tables 5 show the results of heterogeneity analysis. This article divides the sample into economically developed and economically underdeveloped regions based on the different provinces and cities where the enterprises are located. From the results of Table 5, it can be seen that for the overall innovation level of enterprises, green finance is significant at a 1% significance level in the sample of economically developed regions, with a variable coefficient of 2.588. Both the significance and green finance coefficients are better than those of economically underdeveloped regions. This empirical result validates hypothesis 3.

Table 5 Economically Developed and Underdeveloped Regions

	(1)	(2)	(3)	(4)	(5)	(6)
	Economically developed regions			Economically underdeveloped regions		
	Inno	InnoH	InnoL	Inno	InnoH	InnoL
gf	2.588***	2.656***	0.895***	-1.241*	-0.878	-0.232
	(0.344)	(0.354)	(0.261)	(0.732)	(0.755)	(0.486)
gro	-0.0788	-0.0824	-0.0236	-0.131	-0.183	0.0453
	(0.0563)	(0.0573)	(0.0472)	(0.170)	(0.167)	(0.112)
ope	-0.0124	-0.0133	-0.0118**	0.0357	0.0323	0.0129
	(0.00877)	(0.00885)	(0.00595)	(0.0244)	(0.0244)	(0.0133)
str	-0.700	-0.630	-0.225	0.677	0.844	-0.392
	(0.443)	(0.443)	(0.324)	(0.755)	(0.804)	(0.667)
ROA	-0.563*	-0.464	-1.049***	0.204	0.239	-0.654
	(0.335)	(0.336)	(0.233)	(0.938)	(0.929)	(0.633)
_cons	2.231***	2.032***	0.638***	3.073***	2.741***	0.932***
	(0.255)	(0.262)	(0.197)	(0.431)	(0.465)	(0.275)
N	8836	8836	8836	1344	1344	1344
R^2	0.690	0.689	0.723	0.706	0.710	0.695
adj. R^2	0.656	0.654	0.692	0.671	0.676	0.660

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.3. Robust analysis

Replace the explained variable, as shown in Tables 6. In the robust test, enterprise innovation investment is used as a measure of enterprise innovation level, and the impact of green finance on enterprise innovation is still significant, with an impact coefficient of 1.740, passing the robust test.

Table 6 Replacing the explained Variable.

	(1)	(2)
	Inno	Inno
gf	1.758***	1.740***
	(0.266)	(0.264)
gro		-0.192***
		(0.0378)
ope		0.00731
		(0.00759)
str		-0.0906
		(0.303)
ROA		-0.0466
		(0.248)
_cons	17.23***	17.27***
	(0.155)	(0.187)
N	10180	10180
R^2	0.795	0.796
adj. R^2	0.772	0.773

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Replace the explanatory variable. Green finance can affect the financing structure of enterprises, and the satisfaction of enterprise financing needs can be used as a proxy variable to measure the level of green finance. This article refers to Huang Hongjie's (2020) research and selects the asset liability ratio as the core explanatory variable for green finance. Tables 7 show the robustness tests of models (1), (2), and (3) after replacing explanatory variables. The significance level of the variable after replacing the explanatory variable is consistent with the research conclusion and the original model. The higher the level of green finance development, the higher the level of enterprise innovation. The original model passed the robustness test.

Table 7 Replacing explanatory variables.

	(1)	(2)	(3)
	Inno	InnoH	InnoL
lev	1.636***	1.712***	0.698***
	(0.184)	(0.190)	(0.131)
gro	-0.156***	-0.168***	-0.0469
	(0.0519)	(0.0521)	(0.0435)
ope	-0.00270	-0.00396	-0.00708
	(0.00829)	(0.00830)	(0.00547)
str	-0.398	-0.314	-0.241
	(0.390)	(0.394)	(0.289)
ROA	0.627*	0.766**	-0.512**
	(0.323)	(0.325)	(0.231)
_cons	2.910***	2.717***	0.840***
	(0.173)	(0.174)	(0.126)
N	10180	10180	10180
R^2	0.698	0.698	0.723
adj. R^2	0.664	0.664	0.692

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5. Conclusion and policy recommendations

5.1. Conclusion

This article draws the following conclusion through empirical analysis: green finance has a significant positive promoting effect on enterprise innovation; The driving effect of green finance on efficient innovation of enterprises is greater than that of inefficient innovation; Green finance has a more significant positive promoting effect on enterprises in economically developed regions.

5.2. Suggestions

5.2.1 Respond to national policy calls and vigorously develop green finance

The country should increase its support for green finance and enrich the types of green finance products. Accelerate the establishment of regional collaborative development strategies in high-level

and low-level areas of green finance, achieve resource complementarity, promote the improvement of innovation capabilities of enterprises in the region, improve green production levels, and achieve the national strategic goals of carbon peak and carbon neutrality on schedule.

5.2.2 Expand green finance financing channels and cultivate enterprises' awareness of green development

Enterprises should seize development opportunities, expand green capital financing channels, expand funding sources, increase R&D investment, and improve innovation levels. Taking innovation as the core essence of enterprise development, taking the lead in breaking through the challenges of low-carbon environmental protection, enhancing market competitiveness, seizing market share, and realizing the driving role of green finance in enterprise development. Cultivate the awareness of green development and innovation in enterprises, with green, environmental protection, and innovation as the development direction, focus on new areas of environmental protection, and achieve high-quality economic development.

5.2.3 Promote the coordinated development of green finance and enterprise innovation, and promote China's economic transformation

The coordinated development of green finance and enterprise innovation requires long-term persistence. On the one hand, financial institutions should strive to improve the level and quality of green financial services, seize the opportunities for green transformation in finance, take green as the guide, and seek the common development of financial institutions and enterprises. On the other hand, enterprises need to fully recognize the green development trend of the future economy, establish good cooperation mechanisms with financial institutions, increase capital investment in the green energy industry and green technology innovation fields that are supported by the state, combine enterprise technology innovation with environmental protection, utilize the resource agglomeration function and leverage of green finance, improve industrial structure, promote production mode transformation, and enhance enterprise innovation ability, Contribute to the country's green development.

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