

Green Finance and Firms Innovation: Evidence from China

Yulian Liu, Meidan Lai*

School of Economics, Guangzhou College of Commerce, Guangzhou 511363, Guangdong, China

**Corresponding Author.*

Abstract: With a focus on green finance, this paper utilizes a dual fixed-effect model (DFE) to examine the relationship between enterprise innovation and R&D fund input ratio, as well as the impact of green credit. Through regression analysis, it is apparent that a positive correlation exists between green finance and corporate innovation, which, in turn, bolsters their innovative capabilities and contributes to high-quality economic growth. Additionally, the role of debt repayment risk as an intermediary variable is explored, revealing that green finance does not influence enterprise innovation through this channel.

Keywords: Green Finance; Enterprise Innovation; Due Fixed-Effect Model; Mediation Effect

1. Introduction

Over the last forty years of economic reform and openness, China's rapid economic advancement has exceeded all prior expectations. This rapid development has ushered in a new stage of economic growth, where continuous innovation and creativity are essential for high-quality development. Enterprises play a crucial role in driving this development, and in order to achieve long-term success, they must not only increase their own vitality and creativity, but also prioritize innovation. In today's world, innovation is a key characteristic for enterprises to thrive and expand in the competitive market. It holds a significant place in the development of the national economy.

To introduce the idea that "pristine environments, including clear waters and lush green mountains, hold immense value akin to precious gold and silver.", we need to cultivate the concept of green development, build a more harmonious and green natural environment, and strive to build a beautiful China. To develop the economy, more

emphasis is placed on sustainable development, which requires us to change the development mode and accelerate the green transformation. The notion of sustainable or eco-friendly development through green finance has gained widespread approval among the Chinese populace. We believe that the green economy will certainly be the key direction for the future economic development. Based on this, green finance is the core and the inevitable choice. The adoption of green finance can act as a driving force in directing financial resources toward projects dedicated to green innovation, including low-carbon initiatives, green technology development, and other similar efforts. This can yield favorable effects on both the high-quality advancement of the national economy and the innovation of businesses. Green finance not only offers financial backing for corporate research and development initiatives but also fosters and rewards the transition and enhancement of high-energy consumption and high-pollution companies, thus driving sustainable and top-notch economic progress. Therefore, the primary objective of this paper is to investigate the impact of green finance on corporate innovation.

The influence of green finance on corporate innovation holds noteworthy economic consequences. As the primary drivers of innovation, enterprises rely on scientific and technological advancements for sustainable development, with green finance serving as a crucial source of vitality for this progress. The ongoing advancement of science and technology, along with the beneficial synergy between green finance, embodies a crucial central aspect of the prospective sustainable economy. The impact of green finance on corporate innovation holds considerable social importance. In essence, green finance represents a distinctive financial policy aimed primarily at promoting green sectors and prioritizing these enterprises in funding

allocation. To some extent, it also exerts pressure on high-pollution and high-energy consumption firms, compelling them to undergo transformation. Therefore, green finance will more help enterprises to achieve green innovation, reduce carbon emissions, further improve the living environment of Chinese people, and improve the happiness index of Chinese people. The influence of green finance on enterprise innovation has a certain national strategic significance. In recent times, Chinese government has underscored the significance of adopting a strategy focused on innovation-driven development, fostering high-caliber economic expansion, and upholding the five novel development principles, which encompass innovation, coordination, sustainable development, openness, and inclusive growth.

2. Literature Review

2.1 Green Finance

Green finance has emerged as a prominent subject in academic discourse, with diverse viewpoints from various scholars. For instance, Gilchrist et al. [1] emphasize the significance of green financial instruments, such as green credit and green bonds, as pivotal links between finance and environmental concerns, representing a substantial innovation in environmental protection. According to Xu et al. [2], the primary mechanism by which green finance propels green economic progress is through the innovation of financial tools. They argue that during the early stages of economic development, people primarily focused on their economic interests while neglecting environmental benefits, and green finance can contribute to environmental conservation and foster sustainable economic development. Al Mamun et al. [3] have observed that green finance can aid in advancing environmental protection and governance by reallocating resources from high-pollution and energy-intensive industries to those employing more advanced production methods and environmental technologies. Prior research has predominantly concentrated on assessing the impact of green finance on the expansion of the green economy, the evolution of environmentally related sectors, and the transformation of companies toward eco-friendly practices. The first aspect pertains

to the economic growth effect. The implementation of green initiatives not only creates job opportunities but also contributes to economic enhancements through the growth of renewable energy, paving the way for sustainable development and green economic expansion. Secondly, when it comes to optimizing the industrial structure, Yang et al. [4] have pointed out that the positive aspects and externalities of green finance align with the eco-friendly nature of green industries. Green finance can use its financial instruments to channel funds toward the environmental protection sector, reducing investments in high-energy consumption and highly polluting industries, thereby rectifying the mismatch of financial resources. In addition to fostering the development of a more advanced and logical industrial structure, scholars also acknowledge its significance in aiding corporate progress. By directing internal production resources toward low-carbon and clean projects, green finance can bolster the innovation capabilities of enterprises and enhance their overall performance by focusing on energy efficiency and emission reduction. Nevertheless, the implementation of green policies may lead to more stringent requirements for enterprises seeking loan funds, particularly those associated with high pollution levels. This could significantly reduce their cash flow and place them under considerable strain in terms of financing constraints. As a result, enterprises have to change their business strategies and reduce their productive investment. Thus, more investment in pollution control will be increased. [5].

2.2 Enterprise Innovation

From the research of scholars from all walks of life, innovation has always been their pursuit of research. There are many factors that affect innovation, which can be divided into external environment influence and internal attribute influence. The external environmental factors mainly include macro-industrial policy, fiscal policy, market competition degree, property rights protection, government supervision and so on. Internal attributes mainly refer to the ownership structure, internal governance, financing constraints, entrepreneurial ability and so on. Zhu and Tan [6] argue that government-issued industrial policies can guide the allocation of

social resources, encouraging and promoting enterprise innovation and improving operational efficiency, thereby influencing investor decisions. In highly competitive industries, well-designed environmental regulations can effectively enhance enterprise innovation. Government subsidies can help alleviate these constraints and promote green innovation among enterprises.

2.3 Research on Green Finance and Enterprise Innovation

According to Cui et al. [7], the modes can help the development among listed enterprises, with positive responses from these enterprises towards government policy regulations. Fang and Shao [8] additionally underscore the significant function of green finance in driving regional innovation in green technology. To further bolster advancements in green technology, it becomes imperative to strengthen the regional green finance infrastructure and optimize the influence of technological innovation.

In conclusion, scholars have extensively studied the definition and functional effects of green finance, providing valuable insights for the subsequent research of this paper. Additionally, various factors influencing enterprise innovation have been analyzed and summarized, offering a framework for selecting variables in this study. The objective of this paper is to examine the prospective impact of green finance on corporate innovation through a fresh perspective.

3. Study Design

3.1 Data Sources and Model Settings

3.1.1. Origin and processing of data

By reviewing existing literature and considering data availability, this study has chosen to analyze the basic information, relevant financial indicators, and R&D investments of some of the biggest companies in the last few years. The relevant indicators of this type of credit are mainly derived from the provincial data from 2012 to 2020 in the China Statistical Yearbook and the China Industrial Statistical Yearbook.

For the data sample database mentioned above, this paper performs some processing on the selected data: (1) ST, *ST and financial industry companies in the sample are excluded;

(2) Exclude all or part of the data that is more seriously missing. According to the above screening and sorting, a total of 8163 samples were selected.

3.1.2. Model settings

Considering that individual firms are susceptible to macro factors, in order to eliminate these influences, the model construction in this paper chooses DFE, that is, determining the individual firm (Id) and the year (Year). To begin, we examine the direct influence of green finance on corporate innovation, as depicted in the following model:

$$\text{Innovation}_{i,y} = \beta_0 + \beta_1 \text{GF}_{s,y} + \sum \beta_k Z_{i,y} + d_i + u_y + \varepsilon_{i,y} \quad (1)$$

In this model, y represents the year, s represents the province, and i represents a different business. where Innovation_i , y are the explanatory variables, demonstrating the significance of the R&D finance input ratio for i corporations in y years.. $\text{GF}_{s,y}$ are explanatory variables, denoting the level of green finance development among i enterprises located in province s during y years. $Z_{i,y}$ are the control variables, indicating the performance of the company characteristics of enterprise i in y years, including profitability (Roa), solvency (Lev), operating ability (Sale), enterprise age (Age) and enterprise size (Size). d_i represents the individual effect, u_y represents the DFE, where $\varepsilon_{i,y}$ are random perturbation terms.

3.2. Variable Selection

3.2.1. The interpreted variables

This paper studies the influence of green finance on enterprise innovation. At present, there are three main indicators of enterprise innovation, namely, the patented technology of enterprises, the investment in enterprise innovation and research and the increment of intangible assets of enterprises. Considering that the innovation achievements of some enterprises are not disclosed in the form of patents, and the patent authorization often takes a certain amount of time, and there is a certain lag. Usually, enterprise R&D information is disclosed in their financial reports. Given that it often has a direct influence on R&D activities, the level of innovation within a company can be measured

by its R&D investments and the ratio of these investments to its operating income.

3.2.2. The explanatory variables

Given the significance and scale of this type of economic growth, green credit has emerged as a key component of this sector. Hence, this paper will adopt a similar approach to Zhang et al. [9] by using green credit (GF) as a proxy for green finance. In line with the available data and consistent sample range, this study will evaluate the current state of green finance by examining relevant data from six energy-intensive industries in various provinces, focusing on the proportion of interest expenditures. This can be calculated as follows: $\text{green credit} = 1 - (\text{accrual expenditures of 6 source-intensive trades in provinces})$. The higher the resulting value, the greater the level of green finance development [9].

3.2.3. The intermediary variables

The selected intermediary variable for this study is the debt repayment risk (Risk). This will be used to assess the role of green finance in influencing enterprise innovation behavior. The level of debt repayment risk within a company can be determined by examining the ratio of short-term liabilities to total liabilities. If this ratio is too high, it suggests that the company is at a higher risk of not being able to repay its debts. In such cases, the company may adopt a more conservative approach, limiting their investments in research and development and thus hindering their innovation activities.

3.2.4. Control variables

Considering the innovation of the enterprise and its own internal conditions, may be limited, for other aspects, selected the different variables in the existing data to control the impact of the innovation of the enterprise, these variables include management ability in Table 1.

Table 1. Variable Definition

Type	Symbol	Variable	Calculation method
Variables	Innovation	Enterprise innovation	R&D investment/operating income
Explanatory variables	GF	Green credit	1- (Interest expense of six energy-intensive industries in each province / Interest expense of industrial industry)
Mediation variables	Risk	Debt service risk	Short-term liabilities/total liabilities
	Lev	Solvency	Current assets/current liabilities
	Sale	Ability to operate	Operating income/total average assets
Control variables	Age	Enterprise age	Current Year - The year the business was founded
	Size	Enterprise size	The total assets of the enterprise at the end of the period are taken as natural logarithms
	Roa	Profitability	Net profit/average balance of total assets

3.3 Descriptive Statistics of Variables

The data of listed companies in China (2012-2020) were collated and calculated to

obtain relevant variables and statistical descriptions were obtained, and the results in Table 2.

Table 2. Descriptive Statistical Results

VARIABLES	(1)	(2)	(3)	(4)	(5)
	N	Mean	SD	Min	Max
Innovation	8,163	4.491	7.198	0	342.3
GF	8,163	0.587	0.125	0.0918	0.808
Lev	8,163	2.533	3.903	0.0936	144.0
Sale	8,163	0.681	0.546	0.00664	12.37
Age	8,163	22.74	5.388	12	121
Size	8,163	22.35	1.263	19.09	28.42
Roa	8,163	0.0368	0.0773	-1.130	1.202
Risk	8,163	0.833	0.160	0.106	1.000

By excluding data for missing variables and outliers, the total sample size is 8163. Based on the above table, we can observe that in the

selected sample, the average level of enterprise innovation (Innovation) is 4.491, with a variance of 7.198. The maximum value is

342.3 and the minimum value is 0, indicating a significant variation in the ratio of innovation expenditures to operating income among different listed companies in China. This average level of innovation also suggests a relatively low level of investment in research and development among these enterprises. The extremes of the profitability index (Roa) of the enterprise are -1.13 and 1.20, and the mean and variance are 0.0368 and 0.0773, respectively. The extreme values of the solvency (Lev) of enterprises are 144 and 0.0936 respectively, which are very different, with a gap of more than 100, which to a certain extent reflects the large difference in the distribution of capital structure of Chinese enterprises. The maximum value of the company's operating capacity (Sale) is 12.37 and the minimum value is 0.00664, which is a large difference, indicating that there is still a gap in the income of Chinese listed companies, which in turn affects the tendency of enterprises to innovate. The average age of the enterprise (Age) is 22.74, the variance is 5.388, and the maximum and minimum values are 121 and 12, which to a certain extent indicates that the gap in the distribution of years of listed companies is relatively large. The average size of the enterprise (Size) is 22.35, the variance is 1.263, the maximum value is 28.42, and the minimum value is 19.09, which to some extent indicates that there is a gap between the development scale of the selected companies.

4. Results

4.1 Analysis and Results

Analyzing Table 3, we can see that the relationship between green finance and enterprise innovation is statistically significant. This indicates that the development of green finance has a significant impact on enterprise innovation, with more developed green finance among related enterprises leading to greater R&D investments among listed companies. This, in turn, is conducive to promoting innovation activities within Chinese listed companies. The solvency is positive at a significant rate of 1%, indicating that the solvency and innovation level of the enterprise are directly proportional. Operation and profitability were negatively correlated and

met the test, but the age and size of the enterprise were not significant.

Table 3. Results of Regression Analysis

	(1)
VARIABLES	Innovation
GF	1.800** (0.895)
Lev	0.121*** (0.0214)
Sale	-1.819*** (0.237)
Age	-0.000708 (0.0379)
Size	-0.124 (0.126)
Roa	-6.206*** (0.889)
Constant	7.370*** (2.857)
N	8,163
Number of Firms	907
R ²	0.022

Note: ***, ***, * indicate that the results are significant at the level of 1%, 5%, and 10%, respectively. The table reports the coefficient (Coef.) and the values in parentheses are robustness standard errors.

4.2 Testing for Heterogeneity

In Table 4, the processed data sample will be divided according to the region: east, middle, west regions included in the statistical scope. Among them, the northeast region is the least divided, with only three provinces of Heilongjiang, Jilin and Liaoning. The eastern part mainly includes ten provinces and cities, firstly, the three major cities in Beijing, Tianjin, and Hebei, then covers the eastern coastal Shandong, Jiangsu, Zhejiang and Fujian provinces, and includes Guangdong and Hainan Island in the southeast, plus Shanghai, unified into the eastern region. The western region has the highest number of provinces, with a total of 12 provinces and cities, including Yunnan-Guizhou, Sichuan-Chongqing, Shaanxi-Gansu-Ningxia, Inner Mongolia, Guangxi, Tibet, Qinghai, and Xinjiang. Analyzing the data by region allows for a more comprehensive and visual analysis of the current state.

Table 4. Regional Heterogeneity Tests

VARIABLES	East	Middle	West
	Innovation	Innovation	Innovation

GF	0.974 (0.781)	3.120 (2.373)	2.332*** (0.592)
Lev	0.319*** (0.0601)	0.123 (0.139)	0.118** (0.0489)
Sale	-2.043*** (0.240)	-2.641*** (0.571)	-1.429*** (0.229)
Age	-0.127*** (0.0186)	0.342* (0.196)	-0.0608*** (0.0223)
Size	-0.492*** (0.0542)	-1.351** (0.555)	-0.552*** (0.0824)
Roa	-3.505*** (1.138)	-32.28 (19.69)	0.140 (1.099)
Constant	18.69*** (1.557)	27.44*** (8.365)	16.48*** (2.067)
N	5,801	1,409	953
R ²	0.168	0.078	0.127

Note: ***, ***, * indicate that the results are significant at the level of 1%, 5%, and 10%, respectively. The table reports the coefficient (Coef.) and the values in parentheses are robustness standard errors.

The results in Table 4 show that the impact of green finance on enterprise innovation did not pass the significance test in the eastern and central regions. However, in the western region, this relationship has a regression coefficient of 2.332, with a significance level of 1%. It shows that due to the differences in geographical environment and natural resources in different regions, the focus of their development will be different. As a special financial service, green finance mainly provides investment in specific green industries, financial activities and economic activities such as environmental improvement, climate change, and resource efficiency. In contrast to the eastern and central regions, the western region is home to major industries such as environmental protection, energy conservation, and clean energy.

4.3. Mediation Effect Analysis

The mediation effect model is used to analyze the specific impact channels of green finance on innovation as follows:

$$\text{Innovation} = \alpha_0 + \alpha_1 \text{GF} + \sum \alpha_i \text{Control}_{i,t} + \sum \text{Year} + \varepsilon \tag{2}$$

$$\text{Risk} = \beta_0 + \beta_1 \text{GF} + \sum \beta_i \text{Control}_{i,t} + \sum \text{Year} + \varepsilon \tag{3}$$

$$\text{Innovation} = \gamma_0 + \gamma_1 \text{GF} + \gamma_2 \text{Risk} + \sum \gamma_i \text{Control}_{i,t} + \sum \text{Year} + \varepsilon \tag{4}$$

In the above model, Innovation is the dependent variable enterprise R&D innovation, GF is the independent variable green credit, and Risk is the intermediary variable debt service risk. Research on mediating effects through reference, the following specific steps are taken:

First, test whether the α_1 of model (2) is positive, if it is positive, assume that model (2) is true, otherwise stop the test of the following two models; To test whether the β_1 of model (3) is significant; Finally, the γ_1 and γ_2 of the model (4) are tested whether they are significant.

If β_1 and γ_2 are significant and γ_1 is not, the variable Risk is a complete mediator, but all three are significant, indicating that Risk is a partial mediator. If γ_1 is removed and at least one is not significant, the mediating effect requires the Sobel and Bootstrap test. The regression results in Table 5.

Table 5. Channel Mechanism of Green Finance Affecting Enterprise Innovation: Debt Service risk (Risk)

VARIABLES	(1)	(2)	(3)
	Innovation	Risk	Innovation
Risk			-0.256 (0.559)
GF	1.800** (0.895)	0.0333* (0.0188)	1.808** (0.895)
Lev	0.121*** (0.0214)	-0.00344*** (0.000451)	0.120*** (0.0215)
Sale	-1.819*** (0.237)	0.0483*** (0.00498)	-1.806*** (0.238)
Age	-0.000708 (0.0379)	-0.000523 (0.000796)	-0.000842 (0.0379)
Size	-0.124 (0.126)	-0.0399*** (0.00264)	-0.134 (0.128)
Roa	-6.206*** (0.889)	0.0939*** (0.0187)	-6.182*** (0.891)
Constant	7.370*** (2.857)	1.690*** (0.0601)	7.802*** (3.009)
N	8,163	8,163	8,163
R ²	0.022	0.056	0.022
Number of Firms	907	907	907

Note: ***, ***, * indicate that the results are significant at the level of 1%, 5%, and 10%, respectively. The table reports the coefficient (Coef.) and the values in parentheses are robustness standard errors.

The regression results indicate that (1) represents the total influences of green finance

of enterprise reform. Taking into consideration the debt repayment risk in column (2), it could be observed that the influence of this type of economic on enterprise innovation remains significant, with a regression coefficient of 0.0333 at a significance level of 10%. This suggests that for every unit of green finance development, the debt repayment risk of enterprises will increase by 0.0333. In column (3) of the table, when the intermediary variable

debt service risk is added to the original model (2) to form a new model, the regression coefficient of debt service risk is -0.256 in the regression result, and it is not significant, which is in line with the last result of the above steps, that is, γ_2 is not significant, and further Bootstrap test is required for the mediating role of debt service risk. The test results are in Table 6.

Table 6. Bootstrap Test Results

	observed coefficient	Bootstrap std. err.	z	P> z	Normal-based [95% conf. interval]	
bs 1	0.139479	0.0552347	2.53	0.012	0.0312211	0.247737
bs 2	3.28268	0.3988503	8.23	0.000	2.500948	4.064413

From the table above, there is 0 BS1 in the 95% confidence interval, indicating that there is no mediating effect. This means that green finance cannot affect enterprises' investment in innovation and research and development by affecting their debt service risk.

5. Conclusions and Recommendations

5.1 Conclusion

We investigate the data from A-share listed companies in China from 2012 to 2020 to examine the impact of green finance on enterprise innovation. It also explored the role of green credit development levels on enterprise R&D and innovation, and tested for regional differences. Furthermore, the study examined the intermediary effect of green finance in promoting enterprise innovation by mitigating debt repayment risks. The following are the conclusions drawn from this research. Firstly, the findings indicate that green finance exerts a substantial influence in fostering corporate innovation. The empirical assessment demonstrates that, usually, elevated levels of green finance in the economic landscape correlate with heightened innovation capabilities in companies. This implies that the promotion of green finance development can efficaciously incentivize enterprises to participate in innovation initiatives and improve the overall efficiency of capital utilization in the economic setting. Secondly, Evident regional disparities are observed in the effects of green finance. This study scrutinizes the influence of green finance development on corporate innovation within each province of China. The findings underscore the significant role of this form of

finance in advancing corporate reforms in the western regions of China. This can be attributed to variations in regional economic development and the distinct emphasis of this financial approach on green and clean industries. Given that many of these industries are situated in the western regions, the impact of this financial approach in stimulating innovation among enterprises is notably more pronounced compared to the eastern and central regions. .

Thirdly, our results also reveal that green finance does not have a significant impact on enterprise innovation by influencing debt servicing risks.

5.2 Recommendations

Based on the research findings in this paper, it can be concluded that the development of green finance has a considerable impact on promoting enterprise innovation, with notable regional differences.

5.2.1. Expand the environmentally friendly economy

In comparison to the more developed economic environments, the development of green finance in China lags behind and remains relatively weak. This can be seen in the limited availability and variety of green financial products, such as credit, bonds, and carbon finance instruments. The majority of green finance products are focused on green credit, and the overall volume of these products is relatively small. Therefore, there is potential for further development in this area. To improve the green financial system, the following aspects can be addressed: given that green industries have less collateral assets for

development expenditures, there are limitations in their ability to obtain financing.

5.2.2. Boost the significance of environmental economy

Green finance has the potential to drive enterprise innovation and support high-quality economic development, but its development is hindered by regional disparities. In China's "top-down" development model for green finance, the government plays a significant role. As such, local governments should develop fiscal and taxation policies and institutional arrangements that align with their specific development models and characteristics. This includes incorporating green finance into medium- and long-term development plans, enhancing coordination and cooperation among financial, industrial, environmental, fiscal, and taxation policies, and actively guiding more financial capital towards investment in the green economy to foster sustainable economic and green finance development. Additionally, combining inclusive finance with green finance can further facilitate its development. As green finance primarily serves large enterprises in key industries, the coverage for inclusive groups such as small and micro enterprises remains low.

5.2.3. Practice green financial development and enhance enterprise innovation

Since our findings reveal that consumer attitudes, consumption patterns, and preferences significantly influence enterprises' product innovation, it becomes imperative to cultivate a deeper green culture, heighten environmental awareness among the public, proactively promote green consumption concepts, and encourage consumers to opt for resource-efficient and recyclable products. Consumer demands can indirectly stimulate technological innovation within enterprises. Secondly, from the perspective of businesses, it is essential to reinforce corporate social responsibility awareness, take a proactive stance in shouldering social responsibilities, actively align with the national green finance development and innovation-driven development strategy, and bolster internal enterprise motivation.

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