



A Study on the Impact of Green Innovation of Listed Companies on Debt Maturity Structure

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Abstract. The paper tests the impact of green innovation of listed companies on the debt maturity structure, and examines the adjustment effect of debt scale and the heterogeneity of property rights by taking the sample of the listed companies of Shanghai and Shenzhen Stock Exchanges from 2010 to 2019. The findings are that, firstly, there is significantly positively correlation between the debt maturity structure of listed companies and its green innovation, and the debt scale has a negative moderating effect on the relationship for them. Secondly, based on the above relationships, there is more significant in state-owned enterprises than in non-state-owned enterprises. Therefore, enterprises should vigorously strengthen green innovation and properly control the scale of debt, which being beneficial to optimize the debt maturity structure and achieve sustainable development. Especially, state-owned enterprises should assume more green responsibilities.

Keywords: Green Innovation · Debt Maturity Structure · Debt Scale

1 Introduction

On the Fifth Plenary Session of the 18th Central Committee of the Communist Party of China, the government put forward the development concept of “Innovation, Coordination, Green, Openness and Sharing”. The environmental protection awareness of enterprises has been increasing. Many enterprises have increased investment in environmental protection, energy conservation and emission reduction technologies and strengthened their innovation and the concept of green innovation emerges. In 2020, Chinese government had proposed the strategic goals of carbon peaking by 2030 and carbon neutrality by 2060, which raising green and low-carbon development to an unprecedented strategic level.

In order to achieve green development, a series of green financial policies have been introduced continuously. In July 2007, the “Opinions on Implementing Environmental Protection Policies and Regulations to Prevent Credit Risks” was jointly issued by the State Environmental Protection Administration, the People’s Bank of China and the China Banking Regulatory Commission, which marking the full implementation of China “green credit” policy. On September 21, 2015, the “Overall Plan for Ecological Civilization System Reform” was issued by the Central Committee of the Communist Party of China and the State Council clarified the top-level design for the establishment

of China's green financial system at the first time. On December 22, 2015, the People's Bank of China green financial bonds was introduced into the inter-bank bond market, which marking the official launch of China's green bond market.

For the corporate green innovation and debt financing, some research is constantly being developed in the theoretical circle. Now, many theorist mainly focuses on the ability of corporate green innovation to alleviate financing constraints effectively. For example, the green technology innovation effectively alleviated corporate financing constraints [10]. The green innovation in the coal industry will weaken the financing constraints of enterprises [5]. The green technology innovation can not only directly alleviate the financing constraints faced by heavily polluting enterprises, but also significantly enhance the correlation between the quality of carbon accounting information disclosure and financing constraints [3]. But, there are few literature on corporate green innovation and debt maturity structure. And, there is a lack of existing studies on the empirical research of green innovation of listed companies. Due to the difficulty of obtaining objective data such as green patents and green R&D, there are few studies using these objective methods to measure green innovation, and most of them use questionnaire survey measures, which being weak in objectivity and cannot accurately reveal the reality of green innovation [9]. This paper adopts green patents to measure green innovation, and uses an empirical method to test the impact of corporate green innovation on the maturity structure of debt and the adjustment effect of debt size, some innovation.

2 Research Hypothesis

2.1 Green Innovation and Debt Maturity Structure of Listed Companies

Corporate debt financing mainly includes bank credit financing and bond financing. In the context of green financial policies, the state encourages the development of green economy, circular economy, and low-carbon economy, and supports enterprises to develop energy-saving emission reduction technologies, clean energy technologies, new energy development and utilization, water conservation and utilization, pollution prevention and control, ecological agriculture and forestry, ecological civilization, etc. And, the government also promotes the green transformation and development of enterprises, and helps the adjustment of economic structure and the transformation of development mode. With the implementation of green financial policies, the debt financing of heavily polluting enterprises has been restrained to a certain extent [6]. So, Corporate environmental performance will affect its credit and bond financing. Companies, that violate environmental protection policies or fail to meet environmental performance standards, may lead to consequences, such as huge compensation, administrative penalties, and deterioration of the operating environment [2]. That in turn affects the approval of bank loans and the issuance of bonds. It is beneficial to reducing the level of resource and energy consumption for the ability of enterprises to develop green innovation, which improving the ability and efficiency of renewable energy utilization, reducing the level of pollution emissions, and increasing the ability of sustainable development [7]. If an enterprise had strong green innovation ability, it was a low probability of violating environmental protection policies, and good environmental performance, good sustainable development prospects, and high probability of conforming to green financial policies

[8]. In the long run, its principal and interest of debt are relatively safe, and banks have a strong willingness to finance loans. And, its bond issuance is easy to succeed. It is more likely for companies to obtain long-term bank loans and long-term bonds. Based on the above analysis, we put forward the following assumptions:

H1: there is significantly positively correlation between the green innovation of listed company and its debt maturity structure. The stronger the green innovation ability, the greater the possibility of obtaining long-term bank loans and long-term bonds payable, and the higher the proportion of long-term bank loans and long-term bonds payable in total interest liabilities.

2.2 The Impact of Listed Company Debt Scale on Green Innovation and Debt Maturity Structure

Enterprises with strong green innovation ability have strong sustainable development ability and are more likely to obtain long-term financing from the credit market and bond market [1]. Compared with companies with smaller debts, companies with larger debts would face greater pressure on debt repayment. And, their financial indicators may deteriorate, and their solvency may decline. They may even face financial risks too, and their long-term debt financing capabilities may decline. To control their own risks, banks and bondholders have weakened their willingness to raise funds [4]. Therefore, on enterprises with large debts, it is weakened for the positive correlation between their green innovation capability and debt maturity structure, namely the promotion effect of green innovation capability on long-term debt financing being weakened. Based on the above analysis, we put forward the following assumptions:

H2: The debt scale of listed companies negatively should adjust the relationship between green innovation and debt maturity structure.

3 Study Design

3.1 Sample Data

The paper gets the sample of the listed companies on the Shanghai and Shenzhen Stock Exchanges from 2010 to 2019, which excluding financial companies, ST, *ST companies and samples with missing related variables. So, 9250 observations were finally obtained. Then, we use Python software to capture the green patent data of listed companies from the website of the State Intellectual Property Office, and other data from the GuotaiJunan Securities database.

3.2 Variable Definition

3.2.1 Explained Variable

The explained variable is the debt maturity structure. Because it is mainly reflected in long-term bank borrowings and long-term bonds payable for the impact of green

financial policies on long-term debt financing of enterprises, the debt maturity structure is measured by the ratio of the sum of the average long-term bank borrowings and average bonds payable to the average total interest-bearing liabilities.

3.2.2 Explanatory Variables

The explanatory variable is enterprise green innovation. According to the practice of Zhang Junmin and Wang Xiaopi, corporate green innovation is measured by the natural logarithm of the sum of the number of listed companies' green patent applications and 1 [11].

3.2.3 Adjustment Variables

The adjusting variable is the size of the debt. It is measured by the ratio of average total interest-bearing liabilities to average total assets.

3.2.4 Control Variables

Based on the existing research results, we select the following control variables, including return on assets, asset-liability ratio, fixed asset ratio, operating income growth rate and industry concentration of listed companies. The specific variable definitions are shown in Table 1.

Table 1. Variable Definition Table

Variable nature	Variable name	Variable symbols	Variable Definitions
Explained variable	Debt Term Structure	DMS	(Average long-term borrowings + average bonds payable)/average total interest-bearing liabilities
Explanatory variables	Green Innovation	GI	The natural logarithm of the sum of the number of green patent applications of listed companies and the sum of 1
Moderator	Debt size	DS	Average total interest-bearing liabilities/average total assets
Control variable	Return on Assets	ROA	The ratio of net profit at the end of the period to the average total assets
	Assets and liabilities	ALR	Book value of liabilities at the end of the period/Book value of assets at the end of the period
	Fixed asset ratio	TP	Fixed assets/total assets at the end of the period

(continued)

Table 1. (continued)

Variable nature	Variable name	Variable symbols	Variable Definitions
	Operating income growth rate	GROR	(Operating income of the current period - operating income of the previous period)/operating income of the previous period
	Industry Concentration	HHI	The sum of the squares of the percentages of the total industry revenue of each market competitor in an industry.

3.3 Model Design

TO test Hypothesis 1, we examine the impact of listed companies' green innovation on debt maturity structure, and establish models (1) and (2).

$$\text{DMS} = \alpha + \beta_1 \text{GI} + \varepsilon \quad (1)$$

$$\text{DMS} = \alpha + \beta_1 \text{GI} + \beta_2 \text{control} + \varepsilon \quad (2)$$

To test Hypothesis 2, we examine the moderating effect of listed company debt scale on the relationship between green innovation and debt maturity structure, and establish model (3).

$$\text{DMS} = \alpha + \beta_1 \text{GI} + \beta_2 \text{DS} + \beta_3 \text{GI} * \text{DS} + \beta_4 \text{control} + \varepsilon \quad (3)$$

4 Results and Analysis

4.1 Descriptive Statistics

It can be seen from Table 2 that the average debt maturity structure of listed companies is 0.3746, the minimum value being 0, and the maximum value being 1. The average value of green innovation is 0.3793, the minimum value being 0, and the maximum value being 6.7708. The average debt scale is 0.1945, and the minimum value being 0.3793. 0, the maximum value being 0.9152.

4.2 Regression Analysis

In order to examine the impact of green innovation on the debt maturity structure, we test models (1) and (2). The results are shown in columns (1) and (2) of Table 3. The regression results of model (1) show that the correlation coefficient between the debt maturity

Table 2. Descriptive statistics of main variables

	Mean	Standard deviation	Minimum	Median	Maximum value
DMS	0.3746	0.2941	0.0000	0.3607	1.0000
GI	0.3793	0.8285	0.0000	0.0000	6.7708
DS	0.1945	0.1615	0.0000	0.1726	0.9152
ROA	0.0386	0.0639	-1.1500	0.0335	0.6754
ALR	0.4627	0.2064	0.0103	0.4614	1.7584
TP	0.2357	0.1746	0.0001	0.1995	0.9542
GROR	0.1820	1.6230	-1.3100	0.0865	84.9920
HHI	0.1228	0.1237	0.0184	0.0859	1.0000

structure of listed companies and green innovation capability is 0.0218, which being significant at the 1% level. The regression results of model (2) show that the correlation coefficient between the debt maturity structure of listed companies and green innovation capability is 0.0127, which being significant at the 1% level. The findings are that the green innovation ability of listed companies is beneficial to optimize the debt maturity structure, and to obtain long-term bank loans and long-term payable bond financing, and increase the proportion of long-term debt in total liabilities. The hypothesis 1 is verified. Therefore, under the background of green financial policies, listed companies strengthen the research and development of green technology and improve the level of green innovation technology. That will help optimize the debt maturity structure of listed companies and promote the sustainable development of listed companies. For control variables, there is positively correlation between the debt term structure and return on assets, asset-liability ratio, ratio of fixed assets to total assets, and industry concentration respectively.

4.3 Moderating Effect Test

To test the moderating effect of debt scale on the relationship between debt maturity structure and green innovation, we examine the model (3), and the results are shown in column (3) of Table 3. The findings are that the multiplier coefficient of green innovation and debt scale in model (3) is -0.0958 , which being significant at the 1% level. That shows that the debt scale of listed companies has a negative moderating effect on the correlation between debt maturity structure and green innovation capability, which verifies Hypothesis 2. It is more obvious in listed companies with larger debts for the promotion effect of green innovation ability on debt maturity structure.

Table 3. Full sample empirical test results

	(1)	(2)	(3)
	DMS	DMS	DMS
GI	0.0218 *** (4.4457)	0.0127 *** (2.6674)	0.0432 *** (4.8328)
DS			0.6202 *** (15.2578)
GI*DS			-0.0958 *** (-2.8651)
ROA		0.7453 *** (8.4391)	0.8071 *** (9.3518)
ALR		0.4352 *** (18.1617)	0.0993 *** (3.0962)
TP		0.0864 *** (3.7768)	-0.0517 ** (-2.1303)
GROR		-0.0063 * (-1.6853)	-0.0070 * (-1.9185)
HHI		0.1886 *** (5.8002)	0.2173 *** (6.8373)

Note: ***, **, * indicate that the coefficients are significant at the 1%, 5%, and 10% levels, respectively. Below the coefficients in columns (1)–(3) are the T values.

4.4 Group Inspection Based on Property Rights

To study the impact of property rights on the relationship between debt maturity structure and green innovation, as well as the adjustment effect of debt scale, the study was conducted on state-owned enterprises and non-state-owned enterprises respectively. The results are shown in Table 4. Among SOEs, the correlation coefficient between debt maturity structure and green innovation is 0.0182, which being significant at the 1% level, as shown in column (1). This shows that it is beneficial to optimize the debt maturity structure for the green innovation ability of state-owned enterprises. In column (2) of Table 4, the multiplier coefficient of debt scale and green innovation is -0.1005 , and it is significant at the 5% level. This shows that the debt scale of state-owned enterprises has significantly weakened the role of green innovation capacity in promoting debt maturity structure.

Among non-state-owned enterprises, the correlation coefficient between debt maturity structure and green innovation is 0.0103, which being not significant, as shown in column (3). In column (4), the multiplier coefficient of debt scale and green innovation is -0.0726 , which being not significant. This shows that the debt scale of non-state-owned enterprises has no significantly moderating effect on the relationship between green innovation capacity and debt maturity structure.

Table 4. Empirical test results based on the nature of property rights

	State-owned Enterprise		Non-state-owned Enterprise	
	(1)	(2)	(3)	(4)
	DMS	DMS	DMS	DMS
GI	0.0182 *** (2.9275)	0.0393 *** (3.5140)	0.0103 (1.3467)	0.0340 ** (2.3386)
DS		0.7186 *** (14.7524)		0.4856 *** (6.9011)
GI*DS		-0.1005 ** (-2.4929)		-0.0726 (-1.2373)
ROA	1.2593 *** (9.6337)	1.3118 *** (10.4016)	0.3056 *** (2.6105)	0.3652 *** (3.1503)
ALR	0.3678 *** (11.1669)	-0.0407 (-0.9710)	0.4316 *** (11.9661)	0.1778 *** (3.4853)
TP	0.1536 *** (5.6818)	-0.0122 (-0.4288)	-0.1710 *** (-3.8923)	-0.2800 *** (-6.0487)
GROR	-0.0011 (-0.1821)	-0.0054 (-0.9229)	-0.0092 ** (-1.9943)	-0.0082 * (-1.8068)
HHI	0.2494 *** (6.3133)	0.2924 *** (7.6676)	-0.0558 (-0.9850)	-0.0552 (-0.9850)

Note: ***, **, * indicate that the coefficients are significant at the 1%, 5%, and 10% levels, respectively. Below the coefficients in columns (1)–(4) are the T values.

5 Conclusions

5.1 Research Conclusions

Through empirical testing, the following conclusions are drawn:

Firstly, the debt maturity structure of listed companies is significantly positively correlated with green innovation capability, indicating that it is conducive to obtaining long-term debt financing for the improvement of listed companies' green innovation capability, including long-term bank loans and bonds payable, and optimizing the debt maturity structure.

Secondly, the debt scale of listed companies negatively adjusts the relationship between debt maturity structure and green innovation capability. Compared with listed companies with larger debts, it has a more significant role in promoting debt maturity structure for the green innovation ability of listed companies with smaller debts.

Thirdly, in state-owned enterprises, there is significantly positively correlation between its debt maturity structure and green innovation capacity, and the negative moderating effect of debt scale is also significant. However, it isn't significant in non-state-owned enterprises.

5.2 Policy Recommendations

Based on the above research, this paper puts forward the following suggestions:

Firstly, enterprises should vigorously strengthen green innovation. Under the guidance of the carbon neutral strategy, the economic development mode is being profoundly changed, and the green financial system is being constantly developed and improved. It has had a huge impact on the financing of enterprises because of the green credit and green bond policies. Enterprises should meet the needs of the transformation and development of the national economy. They should vigorously strengthen the research and development, innovation and application of green technologies, continuously saving energy and reducing emissions, improving the efficiency of resource and energy utilization, utilizing renewable energy, developing a circular economy, and promoting the green development of enterprises. By continuously improving green innovation capabilities, enterprises can obtain green long-term credit, issuing green bonds, optimizing debt maturity structure, reducing financing costs, promoting sustainable development of enterprises, and supporting high-quality development of the national economy.

Secondly, companies should properly control the scale of debt. Enterprises should implement a prudent financial strategy and maintain a reasonable level of debt. Its excessive debt scale will bring debt risks to the enterprise, and affect the solvency of the enterprise, the enterprise's access to green long-term bank loans, and the issuance of green long-term bonds by the enterprise. By optimizing the debt maturity structure of enterprises, it is not conducive to reducing financing costs and hindering the sustainable development of enterprises.

Thirdly, state-owned enterprises should take on more green responsibilities. As an important pillar of the national economy, state-owned enterprises have the ability and responsibility to play their due role in the process of economic green transformation. State-owned enterprises cover all aspects of the national economy, such as coal power, petroleum and petrochemical, chemical and paper, machinery manufacturing, steel, cement, non-ferrous metals, etc. Many state-owned enterprises are faced with environmental protection problems, such as high energy consumption, high pollution and high emissions, So, they need urgently strengthen green innovation, realizing the green transformation of production and manufacturing methods, using green productivity to improve the vitality and market competitiveness of state-owned enterprises, and taking green financing to optimize state-owned enterprises. Through the debt maturity structure, Enterprise could reduce financing costs, improving the profit creation capacity of state-owned enterprises, and realizing the sustainable development of state-owned enterprises.

Further research suggestions: Some questions will be further studied on how different types of green innovation activities, such as green process innovation, green technology innovation, and green product innovation, Green organization innovation, etc. These will affect the maturity structure of corporate debt, long-term credit and long-term bonds.

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