Green Innovation, Environmental Information Disclosure and Firm Value

Yunlu, Pan

(Wuhan University of Technology, Wuhan, 430070)
panyunlu@whut.edu.cn

Abstract
Under the background of the "dual carbon" strategy, China attaches more and more importance to high-quality green development, which requires firms to assume environmental responsibility, formulate green and sustainable plans, and take the initiative to respond to national policies. This paper selected the panel data of A-share listed firms in the Shanghai and Shenzhen Stock Exchange from 2008 to 2020 to conduct an empirical study on the relationship between green innovation and firm value. The results show that green innovation has a significant positive effect on firm value: firms with strong green innovation capability have higher firm value. Meanwhile, the positive moderating effect of environmental information disclosure on the relationship between green innovation and firm value is further tested. This paper provides a theoretical basis for firms to balance economic and environmental benefits and maximize benefits.

Key words: *Green Innovation, Environmental Information Disclosure, Firm Value*

1.Introduction

In September 2020, China, for the first time, proposed a two-stage carbon emission reduction target ("dual carbon" strategy), which aims to have carbon dioxide emissions peak before 2030 and achieve carbon neutrality before 2060. In the context of promoting the implementation of the "dual carbon" strategic goal and economic transformation and upgrading, green innovation, as the core driving force for the realization of the "dual carbon" goal, not only provides practical methods for carbon drop, pollution decreasing, and greening at the technical level, but also solves outstanding problems such as resource and environmental constraints and cultivates new momentum for high-quality green development and transformation of firms. On the other hand, the goal of maximizing firm value by focusing on economic performance requires consideration of green innovation costs.

Existing studies on green innovation, environmental information disclosure and firm value show that there is no unified conclusion on the relationship between green innovation and firm value. It's mainly in the promotion [1-2] (Xuemei Xie, 2021; Shukuan Zhao, 2022), inhibition [3-4] (Jing Yang et., 2015; Xie, 2022) and nonlinear [5] (Yuhang Qu, 2019) relationships, which may be because the concept connotation of green innovation has not been unified yet. Most studies are based on green patent data or green innovation input data. In addition, few literature studies were conducted on the moderating effect of environmental information disclosure on these two subjects. Recent research on environmental information disclosure has problems such as a short time span, few research samples, and no standard provisions on the content. Some scholars also take the data of Rankins CSR Ratings (RKS) [6] as proxy indicators.

Based on existing research, this paper makes improvements in the following two aspects. First, it sorts out and distinguishes the concept of green innovation in a narrow and broad sense, divides green innovation into high-quality and low-quality according to the quality of green patents and conducts further research on the different impacts on firm value. Second, it selects A-share listed firms in Shanghai and Shenzhen Stock Exchange from 2008 to 2020 as the research samples, uses the environmental research data of CSMAR and its environmental information disclosure index system, and increases the time span of the study to expand the research samples.

Based on the micro-firm perspective, this study explores the impact of green innovation on firm value, enriches the research on the influencing factors, and empirically tests the relationship between green innovation and firm value based on the Porter hypothesis

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and Schumpeter Innovation Theory. The research results help explore the economic motivation behind the green innovation of firms, and further analyze the moderating effect of the level of environmental information disclosure, which will provide a theoretical basis for firms to balance economic and environmental benefits and maximize benefits.

The following parts of this paper are arranged as follows. In the second part, based on the literature review on the relationship between green innovation and firm value, research hypotheses are proposed based on the Porter hypothesis, Schumpeter Innovation Theory, Stakeholder Theory and Signal Transmission Theory, respectively. In the third part, two regression models are constructed for research design. The fourth part is empirical analysis, which tests the relationship between green innovation and firm value, discusses the moderating effect of environmental information disclosure on the relationship between green innovation and firm value, and further analyzes the impact of green innovation quality and firm heterogeneity. The fifth part draws conclusions and the sixth puts forward relevant suggestions.

2.Literature review and theoretical hypothesis

2.1 Green innovation and firm value

Green innovation can be divided into narrow and broad senses. Among them, green innovation in a narrow sense refers to green technological innovation that takes production processes, products or services as the innovation objects, and green innovation in a broad sense also includes green non-technical innovations that take organizational management and business models as the main innovation objects. In this paper, green innovation is defined as green innovation in a broad sense, mainly in green technology innovation[7].

Based on the Porter hypothesis, national environmental regulations such as the environmental responsibility system implemented in the 11th Five-Year Plan (Tao Feng et., 2021), the implementation of Green Credit Guidelines (Wang Xin et., 2021), and the implementation of China's environmental protection tax reform (Liu Jinke, 2022) have a promoting effect on green innovation[8-10]. Furthermore, environmental benefits of green innovation can improve the total factor productivity, promote green transformation and upgrading of firms, and improve firm value.

Based on Schumpeter's Innovation Theory, the driving force of innovation comes from firms' pursuit of excess profits and entrepreneurship. The innovation attribute of green innovation can improve employee performance, product performance and environmental performance, thereby improving firms' economic performance [11] (Zhang Xiaojun, 2012), and it also helps to improve the sustainable development performance of firms[1] (Xie Xuemei, 2021), so as to enhance the core competitiveness of firms and promote firm value.

Based on this, this paper proposes the first research hypothesis as follows:

Hypothesis 1: Green innovation has a significant positive impact on firm value; that is, firms with strong green innovation capability have higher firm value.

2.2 Moderating role of Environmental Information Disclosure in the relationship between Green Innovation and Firm Value

Based on stakeholder theory, environmental information disclosure can cultivate and enhance corporate social responsibility and provide an effective way to establish positive interaction between firms and stakeholders. A high level of environmental information disclosure can increase the pressure of external supervision of firms, urge firms to carry out green innovation to fulfill their social responsibilities and meet the expectations of stakeholders to maintain their green image. Green strategies can help firms improve green performance to achieve sustainable development, offset the value loss caused by green innovation input and add effect to the enterprise's economic value, social value and ecological value.

Based on Signal Transmission Theory, environmental information disclosure can reduce the degree of information asymmetry between firms and investors. High-level environmental information disclosure can convey the firm's investment in green innovation, and fully demonstrate the company's performance in environmental management, governance and other aspects, which helps convey the firm's good reputation and image, enhance investors' trust and recognition, alleviate the high investment cost caused by information asymmetry, and attract investment to enhance firm value.

Based on this, this paper proposes the second research hypothesis as follows:

Hypothesis 2: The level of environmental information disclosure has a positive moderating effect on the relationship between green innovation and firm value.

3.Study Design

3.1 Sample selection and data sources

This paper selected the panel data of A-share listed firms in Shanghai and Shenzhen Stock Exchange from 2008 to 2020 as research samples and processes the samples as follows: (1) Listed firms in the financial industry are excluded; (2) ST and ST* firms are excluded; (3) The samples with missing data or abnormal data were removed; (4) After 1% Winsor tail reduction of

continuous variables, 28002 valid samples were obtained. Among them, the measurement indicators of green innovation come from CNRDS, the measurement indicators of environmental information disclosure level and firm value come from CSMAR, and other financial indicators are from Wind.

3.2 Definition of Variables

3.2.1 Explained variables

In this paper, the relative value of the company's asset exchange value and book value is used to measure firm value [12]; that is, Tobin's Q value is selected to reflect firm value.

3.2.2 Explanatory variables

According to the patent data of the State Intellectual Property Office, green technology is more widely distributed in invention patents and utility model patents [13].

In this paper, the number of green patent applications (Patent) is used to reflect the green innovation of firms [9; 14]. In the specific processing, the number of green patent applications added 1 is standardized by taking the natural logarithm. This paper also divides green innovation according to the quality of green patents, selects the number of green invention patent applications (Inven) to reflect high-quality green innovation of firms, and the number of green utility model patent applications (UM) to reflect low-quality green innovation and further studies the different impacts of green innovation on firm value.

3.2.3 Adjustment variables

In this paper, the Environmental Information Disclosure Index (EDI) is selected to reflect the level of environmental information disclosure [15-16]. In the specific processing, the Environmental Information Disclosure Index (EDI) equals the actual score of environmental information disclosure divided by the highest possible score of all indicators (42 points). The actual score of environmental information disclosure comes from the environmental disclosure data of CSMAR, and its corporate environmental information disclosure index system consists of the following five first-level indicators of environmental management, environmental supervision and certification, environmental information disclosure carrier, environmental liability, environmental performance and governance and other 30 secondary indicators.

3.2.4 Control variables

In this paper, company size (Size), asset-liability ratio (Lev), return on assets (ROA), state-owned enterprise (SOE), cashflow (Cashflow), firmage (Firmage), the shareholding ratio of the largest shareholder (TOP1) and proportion of independent directors (Ind) are selected as control variables [6; 16]. In addition, year and industry effects were controlled.

Table 1 Definition of variables

Variable symbol	Variable name	Specific definition
Explanatory variables		
Patent	Number of green patent applications	Total green innovation, ln (number of green patent applications +1)
Inven	Number of green innovation patent applications	High-quality green innovation, ln (number of green invention patent applications +1)
UM	Number of green utility model patent applications	Low-quality green innovation, ln (number of green utility model patent applications +1)
Explained variables		
Q	Tobin's Q	Firm value, market value B/ total assets
Adjustment variables		

EDI	Environmental information disclosure index	Environmental information disclosure level , Environmental information disclosure score/ total score 42
Controlled variables		
Size	Enterprise scale	ln (total assets of enterprise at year-end)
Lev	Asset-liability ratio	Total liabilities at year-end/ Total assets at year-end
ROA	Return on assets	Net profit/Average balance of total assets
SOE	Nature of equity	Setting State-owned enterprise value 1 and others 0
Cashflow	Cash flow ratio	Net cash flows from operating activities/total assets
Firmage	Establishment year	ln(Current year-year of founded+1)
TOP1	Ownership concentration	Shares held by the largest shareholder/ Total shares
Ind	Independent directors ratio	Number of independent directors / Number of directors
Year	Year	Year dummy variables
Industry	Industry	Industry dummy variables

3.3 Regression model setting

First, in order to verify Hypothesis 1, this paper constructs the following regression model to analyze the impact of green innovation on firm value:

$$Q_{it} = \beta_0 + \beta_1 Patent_{it} + \beta_2 Size_{it} + \beta_3 Lev_{it} + \beta_4 ROA_{it} + \beta_5 SOE_{it} + \beta_6 Cashflow_{it} + \beta_7 Firmage_{it} + \beta_8 TOP1_{it} + \beta_9 Ind_{it} + \beta_{10} industry + \beta_{11} year + \varepsilon_{it} \quad (1)$$

Second, in order to verify Hypothesis 2, this paper introduces the cross multiplication term Patent × EDI, and constructs the following regression model to analyze the moderating effect of environmental information disclosure on green innovation and firm value:

$$Q_{it} = \beta_0 + \beta_1 Patent_{it} + \beta_2 Patent_{it} \times EDI_{it} + \beta_3 EDI_{it} + \beta_4 Size_{it} + \beta_5 Lev_{it} + \beta_6 ROA_{it} + \beta_7 SOE_{it} + \beta_8 Cashflow_{it} + \beta_9 Firmage_{it} + \beta_{10} TOP1 + \beta_{11} Ind_{it} + \beta_{12} industry_{it} + \beta_{13} year + \varepsilon_{it} \quad (2)$$

Among them, i represents firm; t represents year; β0 represents intercept term; ε_{it} represents the residual term; β1 in equation (1) represents the regression coefficient of the dependent variable; β2-β11 represents the regression coefficient of control variables; β2 in equation 2 represents the regression coefficient of cross-multiplication term; β3-β13 represents the regression coefficient of control variables.

4. Empirical test and result analysis

4.1 Descriptive Statistics

Table 2 shows the results of the descriptive statistics. Among them, the minimum value of the total green patent applications is 0, and the maximum value is 4.750, with an average value of 1.180, indicating the overall level of the total green innovation of China's A-share listed firms is not high. The maximum value and minimum value of Tobin's Q in the sample firms are 10.69 and 0.860, indicating a large difference in the evaluation of firm value. The minimum value of EDI is 0, and the maximum value is 0.880, with an average value of 0.160, indicating that the overall level of information disclosure of China's A-share listed firms is not high. The descriptive statistics results of the main controlled variables are basically consistent with the existing studies.

Table 2 Descriptive statistics results

Variable	N	mean	sd	min	max	p25	p50	p75
Patent	28002	0.860	1.180	0	4.750	0	0	1.610
Inven	28002	0.590	0.960	0	4.250	0	0	1.100

UM	28002	0.580	0.930	0	3.910	0	0	1.100
Q	28002	2.540	1.780	0.860	10.69	1.360	1.960	3.050
EDI	28002	0.160	0.150	0	0.880	0.0500	0.100	0.240
Size	28002	22.11	1.310	19.84	26.17	21.15	21.92	22.86
Lev	28002	0.420	0.210	0.0500	0.890	0.260	0.420	0.580
ROA	28002	0.0500	0.0600	-0.200	0.220	0.0200	0.0400	0.0800
SOE	28002	0.390	0.490	0	1	0	0	1
Cashflow	28002	0.0500	0.0700	-0.160	0.240	0.0100	0.0500	0.0900
Firmage	28002	2.790	0.380	1.390	3.470	2.560	2.830	3.040
TOP1	28002	0.350	0.150	0.0900	0.750	0.240	0.340	0.460
Ind	28002	0.370	0.0500	0.310	0.570	0.330	0.330	0.430

4.2 Correlation test

Before regression analysis, the Pearson correlation test (see Table 3) and VIF test showed that the model did not have serious col-linearity problems.

Table 3 Correlation test of main variables

	Q	Patent	Inven	UM	EDI	Size	Lev	ROA	SOE	Cashflow	Firmage	TOP1	Ind
Q	1												
Patent	-0.150***	1											
Inven	-0.163***	0.906***	1										
UM	-0.193***	0.258***	0.741***	1									
EDI	-0.193***	0.258***	0.239***	0.240***	1								
Size	-0.462***	0.415***	0.408***	0.392***	0.416***	1							
Lev	-0.388***	0.169***	0.154***	0.189***	0.125***	0.510***	1						
ROA	0.307***	-0.014**	-0.00700	-0.028***	0.014**	-0.053***	-0.404***	1					
SOE	-0.250***	0.051***	0.065***	0.049***	0.153***	0.346***	0.320***	-0.149***	1				
Cashflow	0.120***	0	0.00500	-0.00800	0.138***	0.053***	-0.151***	0.374***	0.012**	1			
Firmage	-0.113***	0.062***	0.062***	0.045***	0.153***	0.199***	0.170***	-0.128***	0.147***	0.024***	1		
TOP1	-0.062***	0.011*	0.00700	0.034***	0.092***	0.200***	0.062***	0.117***	0.227***	0.087***	-0.125***	1	
Ind	0.056***	0.046***	0.054***	0.040***	-0.00500	0.028***	-0.013**	-0.015**	-0.056***	-0.020***	0.00200	0.043***	1

4.3 Regression Analysis

4.3.1 Regression analysis of green innovation and firm value

This paper conducts regression analysis on green innovation and firm value based on model formula (1). As shown in column (1) of Table 4, the coefficient of green innovation is 0.039, and it is significant at the significance level of 1%, indicating that green innovation can significantly improve firm value, and the empirical results support Hypothesis 1.

4.3.2 Moderating effect of environmental information disclosure level

This paper tests the moderating effect of the level of environmental information disclosure based on model formula (2). As shown in column (2) of Table 4, the cross multiplication term Patent×EDI coefficient is 0.452, and it is significant at the 1% significance level, indicating that environmental information disclosure level can have a positive moderating effect on the relationship between green innovation and firm value. The empirical results support Hypothesis 2.

Table 4 Green innovation and firm value regression results

	(1)	(2)
	Q	Q
Patent	0.039***	-0.052***
	(5.21)	(-4.89)
Patent×EDI		0.452***
		(13.32)
EDI		-0.476***
		(-6.72)
Size	-0.621***	-0.631***
	(-56.55)	(-54.82)
Lev	-0.135**	-0.109*
	(-2.13)	(-1.73)
ROA	7.459***	7.508***
	(30.76)	(31.05)
0.SOE	0.000	0.000
	(.)	(.)
1.SOE	-0.082***	-0.081***
	(-4.38)	(-4.32)
Cashflow	1.037***	0.998***
	(7.04)	(6.75)
Firmage	-0.056**	-0.055**
	(-2.16)	(-2.15)
TOP1	0.263***	0.257***
	(4.76)	(4.66)
Ind	1.764***	1.701***
	(11.50)	(11.11)
_cons	14.295***	14.590***
	(63.96)	(61.94)
N	28002	28002
Year	YES	YES
Industry	YES	YES
df_m	41.000	43.000
r2	0.460	0.463

4.4 Robustness Test

4.4.1 Replacing Explained Variables

In order to avoid the inconsistency of the empirical results caused by the firm value measured by different calculation methods, Tobin's Q value A, Tobin's Q value B and Tobin's Q value D from the CSMAR are used to replace the original variables and re-substitute them into the model. Green innovation and firm value are significantly positively correlated at 1%, 1%, and 10%

confidence levels, respectively, and the conclusion is consistent with the above.

Table 5 Robustness test results: replacing explained variables

	(1)	(2)	(3)
	Q1	Q2	Q3
Patent	0.051***	0.041***	0.020*
	(6.32)	(4.46)	(1.83)
Size	-0.529***	-0.542***	-0.766***
	(-18.03)	(-16.81)	(-23.29)
Lev	0.571**	0.561**	0.244
	(2.38)	(2.19)	(0.86)
ROA	2.793***	2.651***	7.925***
	(4.55)	(4.13)	(10.12)
0.SOE	0.000	0.000	0.000
	(.)	(.)	(.)
1.SOE	0.134***	0.077**	-0.185***
	(4.55)	(2.42)	(-5.15)
Cashflow	0.415	0.610	0.315
	(0.97)	(1.39)	(0.59)
Firmage	0.385***	0.421***	0.101*
	(8.53)	(8.78)	(1.66)
TOP1	-0.522***	-0.771***	-0.143
	(-5.92)	(-8.21)	(-1.30)
Ind	1.717***	1.924***	2.810***
	(7.46)	(7.56)	(9.52)
_cons	10.869***	11.194***	16.814***
	(22.62)	(21.16)	(30.50)
N	28002	28002	28002
Year	YES	YES	YES
Industry	YES	YES	YES
df_m	41.000	41.000	41.000
r2	0.100	0.107	0.175

4.4.2 One-period Lag Test

Since the research and development of green patents has a certain cycle, the impact of total green patent applications on firms has a lag effect. This paper tests the total green patent applications with a lag period. Green innovation and firm value are significantly positively correlated at a 1% confidence level, respectively, and the conclusions obtained are consistent with the above.

Table 6 Robustness test results: one-period lag test

	(1)
	Q
lPatent	0.052***
	(6.55)

Size	-0.579***
	(-50.43)
Lev	-0.227***
	(-3.39)
ROA	7.026***
	(26.76)
0.SOE	0.000
	(.)
1.SOE	-0.106***
	(-5.47)
Cashflow	1.139***
	(7.30)
Firmage	-0.032
	(-1.13)
TOP1	0.271***
	(4.73)
Ind	1.791***
	(11.22)
_cons	14.570***
	(60.97)
N	23903
Year	YES
Industry	YES
df_m	40.000
r2	0.437

4.5 Further research

4.5.1 Quality of Green Innovation

This paper further compares and studies the impact differences of different qualities of green innovation on firm value. As shown in Table 6, the coefficient of high-quality green innovation is 0.082, and low-quality green innovation is 0.024, both of which are significant at a 1% significance level, indicating that high-quality green innovation has a stronger ability to enhance firm value.

Table 7 Green innovation group regression results

	(1)	(2)
	Q	Q
Inven	0.082***	
	(9.32)	
UM		0.024***
		(2.68)
Size	-0.633***	-0.611***
	(-57.39)	(-56.35)
Lev	-0.129**	-0.136**

	(-2.03)	(-2.15)
ROA	7.448***	7.471***
	(30.75)	(30.82)
0.SOE	0.000	0.000
	(.)	(.)
1.SOE	-0.085***	-0.081***
	(-4.52)	(-4.32)
Cashflow	1.044***	1.030***
	(7.09)	(6.99)
Firmage	-0.053**	-0.059**
	(-2.04)	(-2.28)
TOP1	0.275***	0.253***
	(4.99)	(4.60)
Ind	1.741***	1.771***
	(11.35)	(11.54)
_cons	14.535***	14.120***
	(64.60)	(63.90)
N	28002	28002
Year	YES	YES
Industry	YES	YES
df_m	41.000	41.000
r2	0.461	0.460

4.5.2 Firm Heterogeneity

This paper also divides firms according to the nature of equity, and studies the impact differences of green innovation on the value of state-owned firms and non-state-owned firms. As shown in table 7, the coefficient of green innovation of state-owned firms is 0.054, and non-state-owned firms are 0.024, significant at 1% and 5% significance levels, respectively, which indicates that green innovation of state-owned firms has a stronger ability to enhance firm value.

The possible reason is that state-owned firms will actively fulfill social responsibilities, including environmental responsibilities, and the level of environmental information disclosure is higher. On the one hand, based on this study, high-level environmental information disclosure can enhance the role of green innovation in enhancing corporate value by increasing investor trust and conveying a corporate green image to stakeholders. On the other hand, it is found that actively assuming environmental responsibility can enable firms to obtain innovative compensation advantages and first-mover advantages in the long-term development and achieve a win-win goal of economic benefits and environmental benefits .

Table 8 Grouping regression results of equity nature

	(1)state-owned firms	(2)non-state-owned firms
	Q	Q
Patent	0.054***	0.024**
	(5.49)	(2.25)
Size	-0.472***	-0.763***
	(-32.35)	(-46.33)
Lev	-0.461***	0.069
	(-5.40)	(0.78)

ROA	5.360***	8.248***
	(13.48)	(27.68)
Cashflow	0.400*	1.506***
	(1.94)	(7.58)
Firmage	-0.212***	0.027
	(-5.00)	(0.84)
TOP1	0.053	0.259***
	(0.74)	(3.26)
Ind	1.034***	1.571***
	(5.25)	(7.39)
_cons	12.102***	16.770***
	(39.67)	(49.14)
N	10972	17030
Year	YES	YES
Industry	YES	YES
df_m	39.000	40.000
r2	0.404	0.469

5. Conclusions

Taking A-share listed firms in Shanghai and Shenzhen Stock Exchange from 2008 to 2020 as samples, this paper empirically tested the correlation between green innovation and firm value, enriched the literature on influencing factors on firm value, and provided empirical evidence for firms to balance economic and environmental benefits and maximize their benefits. The results show that green innovation is positively correlated with firm value; that is, firms with strong green innovation capability have higher firm value. A high level of environmental information disclosure will enhance the positive correlation between green innovation and firm value. Further research in this paper showed that high-quality green innovation has a stronger ability to enhance firm value and green innovation of state-owned firms has a stronger ability to enhance firm value.

6. Suggestions

Based on this, this paper puts forward the following suggestions: the government should give certain tax incentives or subsidies to firms' green innovation investment to partially offset the adverse effects caused by the rising cost of green innovation investment, and at the same time, accelerate the standardization and construction of the environmental information disclosure system and relevant systems. Mandatory disclosure measures can be appropriately taken to improve the level of environmental information disclosure of firms. Firms should primarily attach importance to green innovation's effect on the promotion of firm value, increase spending on green innovation and improve the quality of green innovation and achievements transformation efficiency. Second, firms should strengthen environmental responsibility, actively respond to national policies, and actively disclose environmental information to improve their green image and further enhance the value-added effect of green innovation on firms.

About the Author

Yunlu, Pan (2002.2-), female, Han nationality, coming from Shiyan, Hubei province, undergraduate student at Wuhan University of Technology, panyunlu@whut.edu.cn, research direction: environmental accounting.

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