Research on the Influence Trend of Green Credit Policy on Innovation Ability and Economic Development of Heavy Polluting Enterprises

Yixuan Wang, Rong Pan*

Tianjin University of Technology, Tianjin, 300384, China

wangyixuan@email.tjut.edu.cn, *panrong@email.tjut.edu.cn

Abstract. In the "carbon neutrality" goal, the green credit policy as an important tool for promoting the green transformation of the industrial structure, urgently needs in-depth exploration of its policy effects. Based on the panel data of Chinese A-share listed companies from 2008 to 2023, this paper analyzes the impact of the green credit policy on the green innovation and economic development of heavy-polluting enterprises by constructing a panel data regression model. The research findings are as follows: First, the green credit policy shows a non-linear characteristic of "short-term inhibition and long-term promotion" on the green innovation ability of heavy-polluting enterprises; Second, the policy effects exhibit significant heterogeneity, with enterprises in coastal areas and private enterprises responding more quickly to the policy; Third, the policy has a promoting effect on green innovation for both heavy-polluting and non-heavy-polluting enterprises, but the marginal effect of the policy on heavy-polluting enterprises is weaker. This study provides theoretical basis and practical implications for improving the green financial policy system and achieving high-quality economic development.

Keywords: Green credit policy, heavy polluting enterprises, green innovation, dynamic evaluation model, regional heterogeneity, ownership heterogeneity, dual carbon target

1 Introduction

Under the background of global ecological environment deterioration, industrial green transformation and low-carbon development have become an inevitable trend of China's high-quality economic development, green credit policy is of strategic significance to promote the transformation of industrial structure by guiding the flow of credit resources to the green economy[16][7].The former State Environmental Protection Administration and the International Finance Corporation of the World Bank formulated the "Green Credit Environmental Protection Guidelines" in 2008, and the China Banking Regulatory Commission issued the "Green Credit Guidelines" in 2012 to promote

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green transformation through credit constraints and incentive mechanisms[5]. However, the policy effects still need to be further discussed[3][4]. Existing research shows that there are differences in the response of heavy polluting enterprises to green credit policies[1][2], and the economic development level of the region where the enterprise is located and whether it is a state-owned enterprise are important factors causing the research differences [6][7][8]. Based on the panel data of A-share listed companies from 2008 to 2023, this paper analyzes the impact of green credit policies on green innovation and economic development of heavy polluting enterprises by constructing A dynamic evaluation model, and identifies the time dynamic evolution law of policy effects, so as to provide a basis for optimizing the green credit policy system and achieving the goal of "dual carbon".

2 Theoretical Analysis and Research Hypotheses

Some scholars have found that green credit policies have financing punishment and investment inhibition effects on heavy polluting enterprises [9][10].Therefore, the financing capabilities of heavily polluting enterprises may be limited[11][12]. And the other scholars show that the implementation of green credit policy overall deter polluting companies green innovation activities, but look from the dynamic effects of the policy, this inhibitory effect weakened [13][14][15]. Therefore, as time goes by, green credit policy may promote the technological innovation and management optimization of heavily polluting enterprises, and improve the green innovation ability of heavily polluting enterprises. Based on the above analysis, this paper puts forward the following hypothesis: the impact of green credit policy on the green innovation capability of heavy polluting enterprises is not a one-way linear relationship, but presents a dynamic track of long-term promotion.

3 Research Design

3.1 Sample and Data Sources

This paper takes all A-share listed companies in China from 2008 to 2023 as the original sample. According to the Industry Classification Management List of Listed Companies for Environmental Protection Verification published by the former Ministry of Environmental Protection in 2008, the industries of the sample enterprises are divided into heavy polluting enterprises and other enterprises, and there are 16 heavy polluting enterprises in total. In addition, a total of 3871 listed companies were obtained after excluding the samples of financial industry companies, ST samples, delisting, termination of listing and negative equity companies.

3.2 Variable Selection and Model Setting

This paper chooses the total amount of green patents granted for utility model as the explained variable, considering the distribution bias of patent data and avoiding the loss

of observed values in the case of zero patents, and takes logarithm of all patent data after adding 1 ; The core explanatory variable of this paper is the green credit policy variable (Post), which is set as the policy dummy variable, and the value is 1 before the implementation of the policy, otherwise the value is 0. In addition, other control variables that may affect enterprise innovation are added, such as enterprise size (size), regional economic level (gdp), asset-liability ratio (Lev), bank loan (totalloan), patent output (patents) and return on assets (ROA). In this paper, panel data regression model is used for empirical analysis, and the model is set as follows:

$$Green_{it} = \alpha + \beta\ Post_{it} + \psi X_{it} + \varepsilon_{it} \quad (1)$$

Where, Green represents the total amount of green utility model patents granted by an enterprise in a certain year; α represents the intercept term of the model, that is, the base of the innovation index in a certain region without the influence of other variables; Post represents the policy impact of a certain enterprise in a certain period; X_{it} Represents each control variable; ε_{it} Is the random disturbance term.

4 Empirical Results and Analysis

4.1 Descriptive Statistics

After screening, a total of 3871 observations were obtained. According to Table1,the descriptive line statistical results of each study variable are shown in the figure. The standard deviation of size is 1.268, and the range reaches a large span, indicating that the scale of sample enterprises is wide; The GDP data range from 4.8 to 10.76, reflecting the obvious differences in the economic level of different regions where the samples are located.

Table 1. Descriptive statistics.

Variable	Observations	Average	Standard devia-	Maximum	Minimum
Green	3871	1.158	1.247	6.659	0
size	3871	22.3	1.268	28.27	18.68
gdp	3871	8.547	1.095	10.76	4.803
Lev	3871	0.882	10.54	391.1	-249
totalloan	3871	0.443	8.693	331.8	-209.2
patents	3871	2.67	2.927	25.32	0
roa	3871	0.045	0.064	1.285	-0.894

4.2 Correlation Analysis

Figure 1 presents the correlation coefficient matrix between the main variables. The green innovation variable is positively correlated with the treatment group, indicating

that green-related enterprises are more likely to be included in the scope of policy intervention; Return on assets (ROA) is moderately correlated with regional economic level (gdp), indicating that the economic environment may affect the profitability of enterprises, thus promoting the innovation behavior of enterprises.

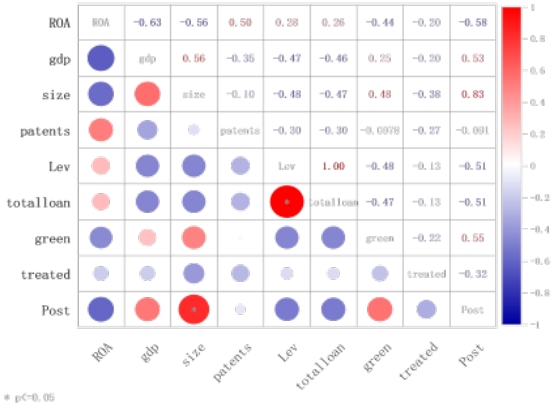

Fig. 1. Correlation analysis

4.3 Benchmark Regression Analysis

To present the influence effect more clearly, this paper also regresses the data of heavily polluting enterprises and non-heavy polluting enterprises for comparison. The regression results are shown in Table 2. Among them, the data marked "(hp)" are the data of heavily polluting enterprises.

Table 2. Regression analysis of heavy polluters and non-heavy polluters.

Variable	Green(hp)	Green(hp)	Green(hp)	Green	Green	Green
	OLS	FE	2SLS	OLS	FE	2SLS
Patents	0.154 * * *	0.155 * * *	0.0963 * * *	0.0451 * * *	0.0468 * * *	0.0938 * * *
	(7.78)	(7.83)	(3.79)	(5.44)	(5.64)	(5.94)
Post	0.657 * * *	0.643 * * *	0.264 * *	0.763 * * *	0.800 * * *	0.251 * * *
	(6.67)	(6.49)	(2.8)	(12.16)	(12.58)	(4.08)
gdp	0.0665	0.0876 *	0.188	0.0237	-0.0153	0.289 * *
	(1.91)	(2.25)	(1.04)	(1.01)	(-0.59)	(3.23)
size	0.532 * * *	0.520 * * *	1.426 * * *	0.649 * * *	0.634 * * *	1.308 * * *
	(3.57)	(3.49)	(4.04)	(6.94)	(6.79)	(6.99)
Lev	-0.0048	-0.00323	0.019	-0.00431	-0.0122	0.0458
	(-0.18)	(-0.12)	(0.88)	(-0.09)	(-0.26)	(0.88)
totalloan	0.0031	0.00128	-0.0242	-0.0246	-0.0143	-0.0706
	(0.1)	(0.04)	(-0.93)	(-0.36)	(-0.21)	(-1.14)
ROA	0.676 *	0.714 *	0.381	0.818 * *	0.802 * *	-0.464
	(2.17)	(2.28)	(0.61)	(-3.19)	(-3.14)	(-0.86)

cons	1.548 * * *	1.630 * * *	4.891 * * *	1.364 * * *	1.105 * * *	5.488 * * *
	(-3.37)	(-3.51)	(-5.87)	(-4.81)	(-3.77)	(-11.69)
N	1168	1168	1168	2703	2703	2703
Region	NO	YES	NO	NO	YES	NO
Adj-R^2	0.2214	0.2224	0.1892	0.177	0.181	0.135
Statistic of	47.12	41.43	12.24	82.79	74.19	13.81
Hausman	0.000	0.000	0.000	0.000	0.000	0.000

The benchmark regression results indicate that the green credit policy has a significant promoting effect on the green innovation capabilities of both heavily polluting enterprises and non-heavy polluting enterprises, but the intensity and mechanism of this effect vary.In heavy pollution enterprise, Post coefficients under the OLS, FE model in non-heavy polluting are lower than in the heavy pollution, thus policy on short-term stimulative effect of polluting enterprises weaker, possible reasons are heavy pollution industry enterprises to carry out green transformation need more efforts in financing, because of high energy consumption and high emission characteristics, heavy pollution industry enterprises need to pay a higher compliance costs, The policy response is relatively lagging. These results preliminarily support the long-run promotion hypothesis. In terms of control variables, the effects of Lev and totalloan are not significant, indicating that the financing constraints of heavy polluting enterprises may come more from policy restrictions than financial structure. The Adj-R^2 of the regional fixed effect model (FE) is higher than that of the OLS model in the regression results of firms in heavy pollution and non-heavy pollution industries, indicating that regional heterogeneity partly explains the differences in green innovation. Therefore, it is necessary to further test and analyze the differences existing in the samples.

4.4 Analysis of Heterogeneity

The economic development levels of various regions in our country vary, thus the impact of the green credit policy on enterprises in different regions also has certain differences [17]; and the nature of the enterprises is also an important factor affecting the regression results [8]. Based on this, this paper groups the total sample by coastal and inland areas for regression analysis and regresses the total sample by public ownership and private ownership to analyze the regional and individual heterogeneity of the samples. The results are shown in Tables 3.

Table 3. Regional heterogeneity analysis.

Variable names	Coastal areas	Inland areas	Public ownership	Private ownership
	Green	Green	Green	Green
	(1)	(2)	(1)	(2)
	FE	FE	FE	FE
Patents	0.0864 * * *	0.0233 *	0.0354 * * *	0.0888 * * *
	(7.36)	(2.08)	(4.29)	(5.98)
Post	0.790 * * *	0.780 * * *	0.711 * * *	0.872 * * *
	(11.12)	(9.44)	(11.65)	(8.27)

gdp	-0.0259	0.0670 *	0.0502 *	0.0615
	(-0.80)	(2.30)	(2.37)	(1.30)
size	0.654 * * *	0.538 * * *	0.686 * * *	0.491 * *
	(6.61)	(4.12)	(7.64)	(3.00)
Lev	0.00435	0.123	0.0696 * *	0.142 * *
	(0.17)	(1.00)	(2.74)	(-2.68)
totalloan	-0.00528	-0.241	0.0827 * *	0.0984
	(-0.18)	(-1.56)	(-2.71)	(1.31)
ROA	-0.297	0.174	0.467 *	0.0110
	(-1.19)	(0.47)	(-1.97)	(0.03)
_cons	1.003 * *	1.440 * * *	1.667 * * *	1.303 *
	(-2.72)	(-3.94)	(-6.13)	(-2.52)
N	2319	1552	2783	1088
Adj-R^2	0.183	0.184	0.179	0.208
Statistic of F	73.83	49.81	86.11	40.46
Hausman test(p value)	0.000	0.000	0.000	0.000

According to the data presented in the regression results, there are significant differences in the policy effects between coastal areas and inland areas. The coefficients of Post and patents are both higher than those in the inland areas. This shows that due to the developed economy and solid technological foundation in coastal areas, enterprises can respond to green credit policies more quickly under the promotion of policies. However, limited by technology reserve and financial support, the effect of green credit policy in inland areas is relatively lagging behind. In addition, the coefficient of gdp in inland areas is significantly positive , indicating that the regional economic level has a significant marginal impact on the green transformation of enterprises.The response mechanism of green credit policy to public and private enterprises is also very different. The Post coefficient of state-owned enterprises is significantly lower than that of private enterprises. The reason may be that public enterprises need to take into account social responsibility and policy compliance, and the transformation is more prudent. Private enterprises are more sensitive to policy incentives due to their high degree of marketization. In addition, the asset-liability ratio coefficient of public enterprises is significantly positive , reflecting that they can obtain transition funds more easily by virtue of the advantages of government credit; However, the coefficient of private enterprises' asset-liability ratio is not significant, indicating that enterprises may face certain financing constraints and need to rely on internal resources to complete technological upgrading.

5 Robustness Test

To verify the reliability of the benchmark regression results, this paper conducts a robustness test on the sample by replacing the dependent variable. The dependent variable is replaced from the total number of authorized utility model green patents (Green) to the total number of authorized green patents (Green*). The data processing method is the same as before, and the regression results are shown in Table 4.

Table 4. Robustness test of heavy polluting enterprises.

Variable	Green*(hp)	Green*(hp)	Green*(hp)	Green*	Green*	Green*
	(1)	(2)	(3)	(1)	(2)	(3)
	OLS	FE	2SLS	OLS	FE	2SLS
Patents	0.154***	0.157***	0.0820***	0.0616***	0.0632***	0.0832***
	(7.27)	(7.42)	(3.30)	(6.91)	(7.07)	(5.13)
Post	0.805***	0.775***	0.340***	0.899***	0.932***	0.301***
	(7.66)	(7.34)	(3.69)	(13.31)	(13.61)	(4.76)
gdp	0.0690	0.114**	0.120	0.0328	-0.00208	0.435***
	(1.85)	(2.75)	(0.68)	(1.30)	(-0.07)	(4.74)
size	0.674***	0.649***	1.921***	0.791***	0.777***	1.482***
	(4.24)	(4.08)	(5.57)	(7.85)	(7.72)	(7.72)
Lev	-0.0225	-0.0192	0.00316	0.00423	-0.00283	0.0509
	(-0.78)	(-0.67)	(0.15)	(0.08)	(-0.06)	(0.95)
totalloan	0.0241	0.0202	-0.00522	-0.0436	-0.0345	-0.0867
	(0.70)	(0.59)	(-0.21)	(-0.59)	(-0.46)	(-1.36)
ROA	1.067**	1.148***	0.230	-1.123***	-1.110***	-0.172
	(3.21)	(3.44)	(0.38)	(-4.07)	(-4.03)	(-0.31)
_cons	-1.820***	-1.996***	-5.506***	-1.716***	-1.484***	-7.023***
	(-3.71)	(-4.03)	(-6.76)	(-5.63)	(-4.71)	(-14.58)
N	1168	1168	1168	2703	2703	2703
Region	NO	YES	NO	NO	YES	NO
Adj-R^2	0.250	0.254	0.209	0.215	0.218	0.156
Statistic of Hausman	55.31	49.34	17.52	105.58	93.63	16.68
	0.000	0.000	0.000	0.000	0.000	0.000

The results show that in the heavy polluting enterprises, the coefficient of the core explanatory variable (Post) still maintains a significant positive impact in the three models, which is consistent with the promotion direction of Post in the benchmark regression, and the significance level does not fluctuate significantly. In addition, the (Patents) is stable around 0.15 in OLS and FE models , indicating that there is a robust correlation between green innovation activities and policy implementation. In the robustness test results of non-heavy polluting enterprises, the Post coefficient is also significantly positive in the three models, and the value is higher than that of heavy polluting enterprises in OLS and FE models, indicating that the promotion effect of green credit policy on non-heavy polluting enterprises is more significant. Among the control variables,consistent with the benchmark regression, the impact of Lev and totalloan is still not significant in the regression results of all kinds of enterprises, which further confirms that the financing constraints of heavy polluting enterprises are more caused by policy restrictions rather than financial structure. The Adj-R^2 is close to the benchmark results, and the model has strong explanatory power and high stability, so reliable conclusions can be drawn.

6 Conclusions

Based on the data of A-share listed companies from 2008 to 2023, this paper systematically analyzes the dynamic impact of green credit policy on green innovation and economic development of heavy polluting enterprises, and draws the following conclusions. In the early stage of the policy, the green innovation activities of enterprises were suppressed due to the high transformation cost and the difficulty of technology upgrading. However, as time goes by, the impact of green credit policy on enterprise green innovation and economic development gradually increases, and the long-term promotion effect is significant. Secondly, the implementation effect of green credit policy is limited by regional and ownership factors. Due to the advantages of technology foundation and capital, the policy response speed of coastal areas is faster than that of inland areas. Due to social responsibility constraints, the policy effect of public enterprises is weaker than that of private enterprises with higher marketization degree. The results of the robustness test show that the promotion effect of the policy on both heavy polluters and non-heavy polluters is robust, while the effect of the policy on the heavy polluters is not significant compared with the non-heavy polluters due to the greater transformation resistance. Based on the research conclusions, in order to better promote the implementation of green credit policies, it is suggested to provide technology subsidies and facilitate the issuance of green bonds for enterprises in inland areas to relieve short-term cost pressure. Financial institutions are encouraged to develop and establish a dynamic interest rate evaluation mechanism, use blockchain technology to integrate enterprise environmental protection and financial data, realize real-time monitoring and sharing of enterprise environmental performance, adjust financing costs according to the progress of enterprise emission reduction, improve the efficiency of credit resource allocation, reduce policy implementation costs, so as to make the policy better play its green constraint role.

7 Further Analysis

Currently, some heavily polluting enterprises (such as Sinopec and Baosteel Group) have responded to the green credit policy by issuing carbon neutrality bonds and green bonds, but their environmental transformation still faces multiple pressures. Besides economic and technical constraints, "internal factors of the enterprises" such as the shortage of environmental protection talents, insufficient regulatory efforts, and the mentality of regarding environmental protection as a burden rather than an opportunity, have led them to be more inclined to invest in "visible" projects rather than truly enhancing resource efficiency. At the same time, the green credit policy also needs to be improved: compared to the innovative financial services of the green banks in the United States, the low-interest rate policy of the ecological accounts in Germany, and the high transparency information guidance in the green finance guidelines in Japan, China's green credit policy has problems such as insufficient targeting, weak preferential measures, and lack of information disclosure standards. Therefore, China urgently needs to strengthen the policy incentive mechanism, improve the standard system, and

enhance information transparency to promote the coordination and cooperation between policies and enterprises, so as to effectively promote green development.

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