

Research on the influence of green credit on green innovation of heavy polluting enterprises

Zhao Ziwei

*School of Economics and Management, Guangxi Normal University, Guilin, China
zhaoziwei63@163.com*

Abstract: *Under the background of "unmoving on the road of ecological priority and green development" as a long-term national strategy, how to effectively play the role of finance and promote the transformation of green development is not only the requirement of high-quality industrial development, but also an important topic to construct the financial theory system with Chinese characteristics. To investigate whether green credit policy can help enterprises' green development by improving investment efficiency, this paper selects A-share listed enterprises in Shanghai and Shenzhen Stock exchanges from 2009 to 2022 as research samples, and uses the Green Credit Policy issued by the former China Banking Regulatory Commission in 2012 as A quasi-experiment to conduct a DID model. This paper empirically tests the mechanism and effect of the implementation of green credit policy and enterprise green technology innovation. The results show that: after the implementation of the Guidelines, the green development of heavy polluting industries has been significantly improved, but there is a lag in the promotion effect, which may be because the heavy polluting enterprises focus on the quality and efficiency of development during the transformation and upgrading of green reform. The process is complex, and it takes some time to transition. Therefore, studying the impact of green credit on the green technology innovation of polluting enterprises has policy reference significance for improving the green financial system and promoting the green development of polluting enterprises.*

Keywords: *green credit; Green innovation; Heavy polluting enterprises*

1. Introduction

Since the reform and opening up, China's economy has achieved rapid development, but the extensive economic development mode, while promoting economic development, has also brought serious environmental problems, which seriously restricts the further development of China's economy. In the face of severe environmental problems, China's environmental protection has been carried out steadily and orderly. Pollution prevention and control work has developed from point source control to non-point source control, river basin control and regional control. The Chinese government is fully aware that the traditional extensive model of economic development cannot be sustained. We must change the mode of development and never sacrifice the environment for temporary economic growth. Since the 18th National Congress of the Communist Party of China (CPC), green development has become a new strategy for governing the country. The concept that "lucid-water and lush mountains are gold and silver mountains" has been deeply rooted in people's hearts, and the building of a resource-saving and environment-friendly society has been accelerated. Strengthening ecological progress and accelerating institutional reform of ecological progress have become a major national strategic policy. To adhere to the path of giving priority to ecology and green development, we should not only rely on government-led environmental regulation characterized by administrative enforcement, but also actively play the role of market incentives to achieve environmental protection by guiding resource allocation. The use of financial means to promote environmental protection and governance, on the one hand, can effectively guide resources from high pollution, high energy consumption industries to the concept of advanced technology in the green field; On the other hand, it can provide more preferential credit funds and wider sources of funds to enterprises actively engaged in green technology innovation to promote the development of green industries (Yin,2016)^[1].

As the main body of market economy and environmental protection, the practice of green development concept by enterprises is not only the micro foundation to promote the smooth implementation of green development strategy at the national level, but also an important vane of economic strategic transformation (Wang,2021)^[2]. Therefore, it is very important to analyze the

development effect of green finance in China from the perspective of corporate green development. At present, Chinese governments at all levels have issued a series of green finance policies to improve the effectiveness of pollution control and promote the green development of enterprises. Green credit can effectively inhibit carbon emissions (Liu,2022)^[3], but at the same time, it will have a crowding out effect on other projects besides green projects and economic aggregate indicators (Wang,2019)^[4].

Under the background that "unmoving the path of ecological priority and green development" has become a long-term national strategy, how to effectively play the role of finance and promote enterprise technological innovation is not only a requirement for achieving high-quality industrial development, but also an important topic for building a financial theoretical system with Chinese characteristics. There is still a lack of research on the impact of green finance on green innovation.

2. Literature review and comment

Green credit policies provide endogenous motivation for enterprises to carry out innovation behaviors. First, green credit affects the direction of enterprise technological innovation. The uncertainty of innovation direction will hinder enterprises' R&D and production. Green credit policy is a market-oriented means of environmental regulation policy, and the strengthening of environmental regulation means will encourage enterprises to produce "innovation compensation effect", which will promote enterprises to make optimal choices, increase R&D investment, innovate technology and improve process under the condition of changing technological innovation direction selection domain (He et al.,2019)^[5]. However, this process has a time lag, and in areas where the intensity of environmental regulation fluctuates strongly, it is often difficult to give full play to the innovation compensation effect of environmental regulation on enterprises (Xie, 2016)^[6]. Second, green credit affects the innovation process of enterprises through the process of environmental regulation. Different from environmental policy tools such as compulsory emission reduction and environmental tax, green credit policy mainly endogenizes corporate environmental costs through financing channels, making enterprises pay for their environmental pollution behavior in terms of credit availability and loan financing cost, compressing their financing space and raising the cost of debt financing. The introduction of green credit policy has changed the incentive structure of enterprises' clean production, forced enterprises to eliminate polluting production technology and carry out technological innovation, and provided internal impetus for enterprises' green transformation. For enterprises, the implementation of green credit policy is a signal of "green development", which has a warning effect on polluting enterprises (Xu et al., 2018)^[7]. In order to eliminate the financing constraints brought by green credit and obtain more funds, enterprises must carry out green innovation, send "green" signals to the market, and try their best to attract investors. However, some scholars hold the opposite view, believing that the implementation of green credit policy inhibits the green technology innovation of enterprises (Li Chao,2022)^[8], which is not conducive to the green development of enterprises, and the inhibitory effect is more significant for high-polluting enterprises with high dependence on external financing and low level of regional environmental regulation (Lu Jing,2021)^[9]. Yu Bo (2021)^[10] also believed that the implementation of the green credit policy inhibited the technological innovation output of heavy polluting enterprises and failed to play the "Porter effect".

The implementation of green credit policy is conducive to guiding the allocation of credit resources to environmental protection and green fields, forcing polluting enterprises to carry out green innovation from the source of enterprise funds, and providing endogenous power for enterprise green innovation. Based on the above analysis, Hypothesis 1 is put forward.

H1: After the implementation of the Guidelines, the green development of heavy polluting enterprises has been significantly improved.

3. Empirical analysis

3.1. Data source

This paper selects the annual panel data of A-share listed companies from 2009 to 2022 as the original sample to measure the development of enterprises' green technology innovation after the implementation of the Green Credit Guidelines in 2012. Among them, the required data of various variables come from CSMAR database. In order to ensure the accuracy of the empirical results, this paper makes the following processing of the original samples by referring to the practice of existing literature: (1) Excluding the

sample data of the financial industry (excluding the financial enterprises because the report format of the financial industry is different from that of general enterprises and the external supervision of the financial industry is stricter, which has a disturbance effect on the decision-making of the research enterprises); (2) the samples of ST, *ST and PT are eliminated; (3) The enterprises listed in B shares during the sample period are excluded (due to the difference between the requirements of B shares market and A shares on the financial data of enterprises, so they are excluded); (4) The enterprises with missing financial data are excluded. Finally, 39884 annual samples of listed companies were obtained, and all continuous variables were winsorized at 1% and 99% quantiles to eliminate the influence of extreme outliers. The data processing and regression process of this paper are mainly carried out in Stata17 software.

3.2. Model construction

In order to avoid sample self-selection bias and endogeneity problems in the research, this paper refers to the practice of Wang Xin and Wang Ying et al. (2021)^[11], adopts the propensity matching different-in-differences (PSM-DID) model, and constructs the following model to analyze the effect of green credit policy on the development of enterprise green technology innovation:

$$\text{Patent}_{i,t} = \alpha_1 + \beta_1(\text{treat}_i \times \text{period}_t) + \gamma X_{i,t-1} + \lambda_i + v_t + \xi_j \times t + \varepsilon_{i,t} \quad (1)$$

Where λ_i represents a series of control variables including enterprise scale, asset-liability ratio, etc.; $\varepsilon_{i,t}$ is the random error term; i and t represent the sample enterprises and time respectively. In order to obtain more robust regression results, this paper controls enterprise fixed effect (λ_i) and time fixed effect (v_t); v_t In order to describe the differences between different industries over time and avoid the potential endogeneity caused by the time-varying characteristics of the industry, this paper adds the industry time trend ($\xi_j \times t$). β_1 is the focus of this paper, which mainly measures the net effect of green credit restricted enterprises on the development of GTI compared with non-restricted enterprises.

4. Statistical analysis and test

4.1. Descriptive statistical analysis

The descriptive statistical results of each variable are shown in Table 1. The statistical variables include the mean, standard deviation, minimum value, 1/4 quantile, median, 3/4 quantile, maximum value and the number of samples. It can be seen that the mean value of enterprise green technology innovation (Patent) is 0.8064, the standard deviation is 1.1627, the maximum value and the minimum value are 0.0000 and 7.3038 respectively, which indicates that there are large individual differences in enterprise green technology innovation. In terms of control variables, the enterprise SIZE (SIZE), Tobin's Q value (TQ) and book-to-market ratio (BM) of each enterprise differ greatly, and the standard deviation is greater than 1. Other control variables, such as corporate growth (Ind) and asset-liability ratio (Lev), have small differences, and the data are relatively stable, which is more in line with the reality of listed companies.

Table 1: Descriptive statistics

Variable names	Observations	Mean	Minimum	p25	Median	p75	Maximum	Standard deviation
Patent	39804	0.8064	0.0000	0.0000	0.0000	1.3863	7.3038	1.1627
Policy	39804	0.8697	0.0000	1.0000	1.0000	1.0000	1.0000	0.3367
Gcres	39804	0.0489	0.0000	0.0000	0.0000	0.0000	1.0000	0.2157
DID	39804	0.0409	0.0000	0.0000	0.0000	0.0000	1.0000	0.1979
Size	39804	22.1459	19.9416	21.2085	21.9492	22.8741	26.0209	1.2855
Lev	39804	0.4167	0.0553	0.2480	0.4077	0.5720	0.8845	0.2076
Cashflow	39804	0.0466	0.1486	0.0076	0.0458	0.0874	0.2318	0.0691
ROA	39804	0.0434	0.2019	0.0150	0.0416	0.0758	0.2109	0.0632
TobinQ	39804	2.0170	0.8552	1.2508	1.6120	2.2984	7.6868	1.2307
Dual	39804	0.2948	0.0000	0.0000	0.0000	1.0000	1.0000	0.4560
Board	39804	2.1217	1.6094	1.9459	2.1972	2.1972	2.6391	0.1971

4.2. Parallel trend hypothesis test

The use of the difference-in-differences method needs to satisfy the parallel trend test. Referring to the practice of Zhang Yan (2022)^[12], the current policy period is used as the base year for verification, and the event study method is used to evaluate whether the parallel trend hypothesis is tested. Three years before the implementation of the policy and ten years after the implementation of the policy are selected to test the parallel trend, and the results are shown in Figure 1. Before the issuance of the Green Credit Guidelines, the coefficient values of the treatment effect are all around 0 at the 99% confidence interval, which means that the parallel trend test passes. In addition, it can be seen from Figure 1 that after the issuance of the Green Credit Guidelines, the development of enterprises' green technology innovation in the early stage is not significant; In the later period, the promotion effect of green credit on enterprises' green innovation level has been significantly improved, which indicates that the policy has achieved ideal results. The above analysis also shows that although the green credit policy has achieved remarkable results, there is a lag effect in this effect.

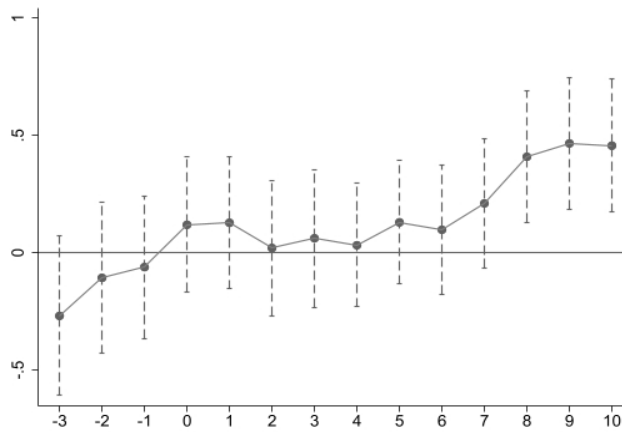


Figure 1: Parallel trend test

4.3. Analysis of regression results

Table 2: Green Credit Guidelines and green development

Variables	(1)GIE	(2)GIE
treat×period	0.2484***	0.3564***
	(0.0000)	(0.0000)
Size		0.4140***
		(0.0000)
Lev		0.0233
		(0.4415)
Cashflow		0.5981
		(0.0000)
ROA		0.0991
		(0.2723)
TobinQ		0.0426***
		(0.0000)
Dual		0.0513***
		(0.0000)
Board		0.0223
		(0.4360)
Industry Time trend	no	is
Individual fixed effects	is	is
Time fixed effects	is	is
Observations	39399	39804
Adjust R	0.6890	0.2502

Note: ***, ** and * indicate significance at the level of 1%, 5% and 10%, respectively; Standard errors in parentheses; Same below.

According to Table 2 in the figure below, column (1) reports the separate effect of the implementation of green credit policy on enterprises' green innovation capability when control variables and industrial

time trend are not added. It can be seen that the coefficient of the interaction term (treat × period) is 0.2484, which is significantly positive at the level of 1%; Considering the impact of omitted variables on the estimation results, control variables and industry time trend are added in Column (2), and the results are still significantly positive at the level of 1%; treat × period In this case, the coefficient of the interaction term (treat × period) is 0.3564, indicating that after the implementation of the green credit policy, the enterprise green development index has increased by 35.64%. Thus, Hypothesis 1 is proved.

4.4. Robustness test

4.4.1. Propensity matching score-difference-in-differences method

This paper uses the radius matching method to construct PSM-DID model to further test the empirical results. Column (1) of Table 3 reports the regression results after the PSM-DID method is adopted. It can be seen that the coefficient of interaction (did) is 0.1210 and significant at the level of 1%. The results are consistent with those mentioned above, which indicates that the benchmark regression results are robust.

Table 3: Results of the robustness test

Variables	(1)PSM-DID	(2) Lag one period	(3) Lag two periods
treat×period	0.3564*** (0.0000)		
L.treat×period		0.2219*** (0.0000)	
L2.treat×period			0.1025** (0.0434)
Contral	is	is	is
Industry time trends	is	is	is
Individual fixed effects	is	is	is
Time fixed effects	is	is	is
Observations	39804	39399	39804
Adjust R	0.2502	0.6890	0.2502

4.4.2. Index lag test

Considering the time lag of green credit policy implementation, enterprises may not be in the same period from being constrained to implementing green technology innovation; And there may be reverse causality between green credit and enterprise green technology innovation, that is, commercial banks will increase support for enterprises with good environmental performance to promote the development of enterprise green innovation. In order to enhance the robustness of the benchmark regression results, Columns (2) and (2) of Table 3 report the regression results of Model (1) with one-period lag and two-period lag of explanatory variables and control variables respectively. The results show that after one lag, the coefficient becomes 0.2219, which is still significant at the level of 1%. After two lags, the coefficient becomes 0.1025 and is still significant at the level of 1%, which further verifies the previous conclusions and shows that the previous analysis results are convincing.

4.4.3. Placebo test

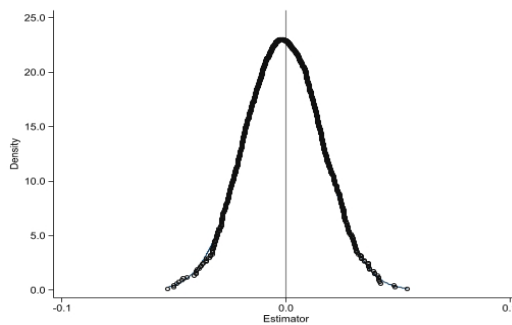


Figure 2: Results of placebo test

Since the results of this paper may be affected by other unobservable factors, this paper refers to the method of Liu (2020)^[13] to construct a placebo test with random selection of experimental groups to determine whether the promotion effect of green credit policy on enterprises' green innovation capability

is caused by other random factors. Firstly, a list of enterprises was randomly selected as the fictitious experimental group, and the experiment was repeated 1000 times. Then, the coefficients of 1000 experiments were calculated by regression. Finally, the corresponding kernel density map was made and compared with the coefficient values in the regression results of the original data. The final results are shown in Figure 2. It can be found that the t-value in the random process is distributed around the value of 0 and follows the normal distribution, which is significantly different from the real coefficient value of 0.249, indicating that the promotion effect of green credit policy on the green innovation capability of enterprises is relatively robust, indicating that the above analysis results are convincing.

5. Policy suggestions and implications

With the steady progress of China's ecological civilization construction and the clarity of the national "dual carbon" goal, green development has become more and more popular. The traditional extensive model of economic development cannot be sustained. We must change the mode of development and unswervingly follow a new path of high-quality development that gives priority to ecology and is guided by green development. Green finance is an important driving force for promoting green innovation and achieving green development. Taking the Green Credit Policy issued by the former China Banking Regulatory Commission (CBRC) in 2012 as a quasi-experiment, this paper conducts a DID model to study the relationship between green credit policy and enterprise green technology innovation, and further analyzes the internal mechanism. The results show that after the implementation of the Guidelines, the level of green technology innovation in heavy polluting industries has been significantly improved, but there is a lag in the promotion effect, which may be because heavy polluting enterprises emphasize on the quality and efficiency of development during the transformation and upgrading of green reform, and the process is complex, which requires a certain period of transition.

Whether the green credit policy can play an effective role mainly depends on the rationality of the policy itself, the effectiveness of implementation and the coping strategies of enterprises. Based on the above conclusions, this paper puts forward the following suggestions:

5.1. *Continue to improve the green credit policy*

From the perspective of policy itself, this paper finds that green credit policy can well promote the green development of enterprises, give full play to the resource-oriented role of financial market, and force enterprises to take the initiative to carry out green reform. Therefore, we need to constantly improve the green credit policy and green financial system, coordinate the contradiction between economic construction and environmental pollution, promote the integration of green finance and energy power, green finance and industrial upgrading, give full play to the resource allocation function of financial market, promote carbon reduction, pollution reduction, green expansion and growth, and promote high-quality economic development.

5.2. *We need to establish an efficient information communication system and a sound enterprise environmental protection evaluation system*

From the perspective of government implementation, the implementation of green credit policy depends on efficient information communication system among various departments and perfect enterprise evaluation system. On the one hand, the government should actively promote the environmental information disclosure system, improve information transparency, ensure the authenticity and reliability of information, solve the problem of information gap between departments to improve work efficiency, guide enterprise stakeholders to make correct decisions, and prevent enterprises from "greenwashing" behavior. On the other hand, the government should promote the enterprise environmental protection evaluation system, provide a unified standard for the implementation of green credit, and improve the motivation of traditional resource-based industries to upgrade technology and strengthen pollution prevention and control. To improve the unified enterprise environmental protection evaluation system, we should not only pay attention to the gap between industries, but also pay attention to the differences in pollutant discharge capacity and energy conservation and emission reduction technology upgrading capacity between different enterprises in the same industry, so as to avoid the blow to the enthusiasm of advanced enterprises in green transformation caused by the gap between enterprises.

5.3. Enterprises should actively promote their own environmental governance and take the initiative to carry out green transformation

From the perspective of enterprise response strategy, as a micro subject, enterprises are an important symbol of national economic strategic transformation and play an important role in the economic market. This paper finds that after the implementation of green credit policy, the green development index of heavy polluting enterprises increases significantly, which indicates that enterprises are actively responding and constantly integrating into the development of green economy. In the process of realizing the green development of enterprises, enterprises should clearly define their own positioning and deal with the relationship between economic performance and environmental performance. On the one hand, from the perspective of their own management, enterprises should fully mobilize the enthusiasm of stakeholders to put environmental protection in an important position when making decisions; Strengthen the internal governance of the company, improve the regulatory agencies, to prevent the lack of investment efficiency caused by the principal-agent problem and only focus on short-term profits while ignoring the long-term development of the enterprise, to combine their own situation and gradually carry out green transformation to achieve sustainable development. On the other hand, from the perspective of enterprise production process: enterprises should actively promote green reform, increase investment in environmental protection, actively fulfill social responsibilities, improve green production equipment and technology, reduce the consumption of resources generated in their own production process, effectively implement the concept of environmental protection, realize the green development of enterprises, improve social recognition and credibility, and make enterprises coruse lasting vitality.

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