The Impact of Green Credit Policy on Green Innovation of Heavy Polluters: Evidence from China

Beifan Zhang
School of economics, Beijing Technology and Business University, Beijing, China
zhangbeifan1101@163.com

Abstract. Based on Green Credit Guidelines released in 2012, this paper analyzes the impact of green credit policy on green innovation of heavy polluters by difference-in-differences model (DID) with data of Chinese A-share listed companies from 2008 to 2019 as a sample. It is found that after the implementation of green credit policy, the green innovation of heavy polluters is significantly inhibited compared to non-heavy polluters and fails to exert the Porter effect. Further studies find that there is heterogeneity in the impact of green credit policy on green innovation of heavy polluters: Compared with green utility patent, green credit policy significantly inhibits green invention patents of heavy polluters. Compared with state-owned enterprises, green credit policy significantly inhibits green innovation of the non-state-owned. Compared with eastern region, green innovation of heavy polluters in central and western region is more inhibited by the policy. This paper further expands and extends the research on the effect of green credit, which has important implications for the corporate green transformation and green development of economy under the green credit policy.

Keywords: Green credit; Heavy polluter; Green innovation; Difference-in-differences model.

1. Introduction

Since the reform and opening-up, China has faced many ecological and environmental issues along with its rapid economic growth. Problems such as overuse of resources and serious environmental pollution have become obstacles for sustainable development, which has become crucial to promote high-quality economic development and high-level ecological and environmental protection in a coordinated manner. In 2020, Xi Jinping proposed at the 75th session of the UN General Assembly to strive to achieve carbon peak by 2030 and carbon neutrality by 2060. "The 14th Five-Year Plan" in 2021 proposed to "adhere to ecological priority and green development, and collaboratively promote high-quality economic development and high-level protection of the ecological environment." In 2012, the former CBRC issued the "Green Credit Guidelines" (hereinafter referred to as the "Guidelines"), which strengthens the environmental and social risk management of banking financial institutions (hereinafter referred to as the "BFI") in the credit granting process, and plays a role in pushing enterprises to green innovation and promoting their green transformation and upgrading.

Green credit has two implications: First, it refers to the national policy, specifically the state's environmental economic policy of achieving environmental protection goals through regulating banks' credit behavior. The second is green credit related to the bank. According to environmental and economic policies, BFIs provide loan support and preferential interest rates to enterprises or institutions in research and production of pollution control facilities, development and utilization of new energy, and restrict loans to polluters (Ge et al., 2015) [1]. In short, green credit serves to guide the flow of funds to green and environmental industries and inhibit them to those that cause harm to the environment and society. Its purpose is to raise the financial industry's concern for the environment and promote the green transformation and development of enterprises. However, Guidelines also brings more stringent financing constraints to some enterprises. Some literature argue that financing constraints have an impact on R&D investment as well as innovation for the enterprises (Ju et al., 2013; Zhang et al., 2017) [2-3]. Will green credit policy promote or inhibit green innovation of heavy polluters?

In terms of theory, research on green credit and technological innovation is mainly based on the "Porter hypothesis" and "institutional impediment theory" (Ji et al., 2021) [4]. Studies based on the

Porter hypothesis suggest that appropriate environmental regulations can induce enterprises to engage in more innovative activities, which will increase their productivity, thus offsetting the costs of environmental protection and increasing their profitability in the market (Porter & Van, 1995) [5]. The "Porter effect" of green credit is achieved by controlling the credit threshold so that heavy polluters or corporate polluting projects face the pressure of financing constraints (Dong&Lian,2018; Ding,2019) [6-7]. The enterprises with better environmental performance are more likely to obtain longer-term and lower-cost external financing (Shen & Ma, 2014; Lian, 2015) [8-9]. Therefore, green credit plays a role in directing the flow of funds to green and environmental industries and increasing the support for sustainable and environmentally friendly projects (Aintablian et al., 2007; Zhao, 2018) [10-11]. In turn, it forces enterprises to strengthen green innovation and achieve green transformation (Hu et al., 2021) [12]. Studies based on the "institutional impediment theory" suggest that the loan size and cost of polluters and projects would deteriorate under green credit policy (Chen, 2019) [13]. The green innovation will take up a large amount of capital and increase the operation and management costs of enterprises, leading to a financial burden. Therefore, enterprises are not motivated to carry out green innovation under environmental regulation (Cui & Jiang, 2019) [14].

In terms of empirical study, most of the existing studies focus on the impact of green credit policy on enterprise technological innovation, and the findings vary widely. Some scholars believed that green credit policy have a significant promoting effect on enterprise technological innovation (Zhang & Lu, 2022; Sun & Shi, 2019) [15-16], especially on the environmental protection enterprises (He et al., 2019) [17]. However, others proposed that green credit policy do not play a role in promoting enterprise technological innovation, and even appear to inhibit the heavy polluters (Lu et al., 2021; Tian & Xiao, 2021) [18-19]. Few studies refine the innovation, specifically on the impact of green credit on green innovation of heavy polluters, while the available studies have inconsistent conclusions. Some argued that green credit policy promotes green innovation in heavy polluters (Liu et al., 2021) [20], and others believed that the policy exerts a perverse impact (Yang & Zhang 2022; Li &Gou, 2021) [21-22].

The main contributions of this paper are as follows. First, this paper further expands and extends the research on the effects of green financing policies by exploring the effects of green credit policy on green innovation of heavy polluters. Second, the data used in this paper are more objective and accurate, and the green patent data come directly from the latest CNRDS database. Currently, most of the green patent data in previous literature is based on the patent database itself. Compared with the green patent data in this paper, the latter one is more objective and accurate. Third, this paper analyzes the heterogeneity of enterprises and finds that the implementation effect of green credit policy is influenced by patent type, enterprise property and region. The heterogeneity analysis helps to identify the differences in the implementation effects of green credit policy and helps to further improve the policies.

2. Theoretical Analysis and Research Hypothesis

2.1 Green Credit and Corporate Green Innovation

In terms of BFIs, after the implementation of the green credit policy (hereinafter referred to as the "implementation"), they will pay more attention to their own green ratings, and take environmental and social risks into account when conducting credit activities. BFIs are more inclined to provide credit concessions and support to environmental protection and energy-saving projects or enterprises. However, corporate green innovation requires long-term and continuous investment and does not necessarily bring returns (Xie & Fang, 2011) [23]. Therefore, when the risks of enterprises are expected to increase in the future, BFIs tend to be risk-averse out of their own interests, and inhibit the flow of funds to corporate innovation (Morck & Nakamura, 1999) [24]. In addition, lending by BFIs to enterprises with environmental accidents may cause reputational damage (Aintablian et al. 2007).

In terms of enterprises, the green development transformation of heavy polluters today is an inevitable trend. The first drive is green innovation, but the large amount of financial support required is difficult to be met by general endogenous financing, and enterprises would only carry out exogenous financing (Zhang et al., 2012) [25]. The loan from BFIs is an important source of external financing for enterprises (Chen,2009) [26]. Green credit policy has a significant financing penalty and investment inhibiting effect on heavy polluters (Su & Lian, 2018) [6]. After the implementation, the financing environment of heavy polluters will deteriorate and they will face greater policy risks.

The essence of environmental regulation is that it transfers environmental costs to enterprises, thus encouraging them to choose environmentally and socially beneficial development strategies (Porter & Linde, 1995) [27]. Under green credit policy, heavy polluters may face risks and uncertainties. At the macro level, enterprises may face risks in terms of legislation, environment, society and finance. At the micro level, it refers to project operation, management and finance. The uncertainty caused by these risks would exert somewhat deviated impact of green credit policy on green innovation (Wang & Lu, 2019) [28]. In light of risks and uncertainties, enterprises are unwilling to engage in green innovation. Based on the above analysis, this paper proposes the following hypothesis regarding the impact of green credit policy on green innovation of heavy polluters.

Hypothesis H1: After the implementation of Guidelines, the green innovation of heavy polluters will be significantly inhibited compared to non-heavy polluters.

2.2 Heterogeneity in the Impact of Green Credit Policy on Green Innovation of Heavy Polluters

(1) Patent Type

Green patent is divided into green invention patent and green utility patent. Compared with utility patent, invention patent is more stringent and have longer examination period, higher creativity and more expensive fees. Therefore, enterprises prefer utility patent which is less difficult, because corporate innovation aims to seek policy support as a strategy, and they tend to pursue quantity rather than quality in the innovation process (Hall & Harhoff, 2012; Li& Zheng, 2016) [29-30]. Under the green credit policy, when companies face more severe financing constraints, they will choose the less costly and difficult green utility patents to "get rid of green". Based on the above analysis, the following hypothesis is proposed.

Hypothesis H2: After the implementation of Guidelines, compared with non-heavy polluters, green invention patents of heavily polluter are significantly inhibited, while green utility patents are not significantly inhibited.

(2) Enterprise Property

On the one hand, there are significant differences between state-owned enterprises (hereinafter referred to as the "SOE") and non-state-owned enterprises (hereinafter referred to as the "non-SOE") in terms of access to bank loans. Compared to SOEs, non-SOEs have more difficulty in obtaining loans from banks, but smaller and higher credit standards (Brandt & Li, 2003) [31]. The reason is that SOEs are likely to receive government bailouts when they are in financial distress and have less risk of defaulting on their debt (Chen et al., 2010) [32]. On the other hand, SOEs, as government-owned enterprises, are charged with national tasks and need to assume environmental and social responsibilities. Therefore, after the implementation of Guidelines, although both SOEs and non-SOEs face financing constraints, SOEs are more likely to have access to resources such as government subsidies. In this sense, SOEs still have ability to carry out green innovation activities, while non-SOEs will be severely inhibited under the dual pressure of financing constraints and credit discrimination. Consequently, the following hypothesis is proposed.

Hypothesis H3: After the implementation of Guidelines, green innovation by non-SOE heavy polluters is more significantly inhibited compared to SOE heavy polluters.

(3) Region

China has a vast territory, with significant differences in the financial market environment among regions. Specifically, the financial development in the east is higher than that in the central and western region. Financial development significantly reduces the financing pressure of enterprises, and the financing constraints of listed companies with higher financial development are significantly lower than those with weaker financial development (Shen et al., 2010) [33]. Therefore, the implementation may be different among regions. Although all heavy polluters face greater financing pressure, it will be alleviated in the east where financial development is higher, which leads to the following hypothesis.

Hypothesis H4: After the implementation of Guidelines, the green innovation of heavy polluters in the central and western region is more significantly inhibited compared to heavy polluters in the east.

3. Study Design

3.1 Sample Selection and Data Sources

This paper uses Chinese A-share listed companies from 2008 to 2019 as the original sample, according to "Guidelines for Industry Classification of Listed Companies" revised by the China Securities Regulatory Commission in 2012, and combines with the "List of Listed Companies' Environmental Protection Verification Industry Classification Management List" formulated by the former Ministry of Environmental Protection in 2008 and the "Guidelines for Environmental Information Disclosure of Listed Companies" in 2010. The heavy polluting industries include 16 industries such as thermal power, iron and steel, and cement. In order to improve the validity of the data, ST, *ST and PT companies, companies with serious lack of relevant data and the sample of listed companies in the financial industry are excluded, and finally 673 listed companies are collected. The data of green patent in this paper are collected from the CNRDS database, and the data related to other enterprises are from the CSMAR database. The variables were winsorized above the 1% and 99% levels before the study.

3.2 Variable Definition

3.2.1 By Explanatory Variable: Corporate Green Innovation (Gpatent)

By explanatory variable uses the sum of green invention patent and green utility patent of listed companies and their subsidiaries to measure green innovation. Patent license requires a longer time for approval with a certain lag, and the patent may already have an effect on the enterprise during the process, so the number of patent application will be more stable, reliable and timely than that of patent license.

3.2.2 Explanatory Variable: Interaction Term of Time and Industry Dummy Variables (Time × Treat)

For the explanatory variable, this paper regards the release of Guidelines as a policy shock and the interaction term of time and industry dummy variables as the core explanatory variables. Time is the time dummy variable after the release of Guidelines and it takes the value of 1 from the year 2012, otherwise it is 0. Treat is the industry dummy variable and takes the value of 1 when the enterprise belongs to a listed company in heavy polluting industry, otherwise it is 0.

3.2.3 Control Variable

Considering that other factors of the enterprise also have an impact on the corporate green innovation, this paper draws from Yu (2021) [34], Li and Liu (2021) [35] and other scholars, and selects the characteristic data of corporate size (Size), asset-liability ratio (Lev), corporate age (Age), total assets growth rate (Growth), profit rate of asset (Roa), tangible assets ratio (Tang), and corporate value (Tq) are selected as control variables. The variables are defined in Table 1 below.

3.3 Empirical Model

To study the impact of green credit policy on green innovation of heavy polluters, the following DID model is constructed with heavy polluters as the experimental group and non-heavy polluters as the control group.

$$Gpatent_{it} = \beta_0 + \beta_1 Time_t \times Treat_i + \gamma Control_{it} + \delta_i + \lambda_t + \varepsilon_{it} \tag{1}$$

The by explanatory variable in equation (1) indicates the green innovation of listed company i in year t; the core explanatory variable Timet × Treati is a DID variable whose coefficient indicates the effect of green credit policy on the green innovation of heavy polluters. Controls is a control variable; δi is an individual fixed effect; λt is a time fixed effect; and εit is a random error term.

Table 1. Variable Definition

Type	Name	Symbol	Description
By Explanatory Variable	Patent Output	*Gpatent*	The sum of green invention patent and green utility patent
Explanatory Variable	DID Variable	*Time × Treat*	Net effect of green credit policy
Control Variable	Corporate Size	*Size*	Total assets are logarithmic
	Asset-liability Ratio	*Lev*	Total Liabilities / Total Assets
	Corporate Age	*Age*	The difference between the current year and the year the enterprise was founded is logarithmic
	Total Assets Growth Rate	*Growth*	(Total assets at the end of the period - Total assets at the beginning of the period)/ (Total assets at the beginning of the period)
	Profit Rate of Asset	*Roa*	Net Income / Total Assets
	Tangible Assets Ratio	*Tang*	Tangible Assets / Total Assets
	Corporate Value	*Tq*	Market Capitalization / Total Assets

4. Empirical Results and Analysis

4.1 Descriptive Statistical Analysis

The results of descriptive statistics for each main variable are shown in Table 2. As seen in Table 2, the average value of the corporate green innovation proxy variable Gpatent is 7.839, with a standard deviation of 25.20, a minimum value of 0, and a maximum value of 194, indicating that green innovation varies widely among different enterprises. In addition, except for the standard deviation of Size and Tq, the standard deviation of other control variables is less than 1.00, which indicates that the overall fluctuation of control variables is slight.

Table 2. Descriptive statistics of main variables

Variables	Observations	Average	Standard Deviation	Minimum value	Maximum value
Gpatent	8,076	7.839	25.200	0.000	194.000
Time × Treat	8,076	0.237	0.425	0.000	1.000
Size	8,076	22.600	1.384	19.980	26.720
Lev	8,076	0.491	0.192	0.077	0.879
Age	8,076	2.812	0.358	1.558	3.434
Growth	8,076	0.131	0.200	-0.259	1.014
Roa	8,076	0.043	0.049	-0.114	0.205
Tang	8,076	0.938	0.079	0.488	1.000
Tq	8,076	1.617	1.475	0.151	8.285

4.2 Parallel Trend Test

To verify the appropriateness of the DID model, a parallel trend test need to be conducted for both control group and experimental group. Figure 1 shows the time trend of corporate green innovation from 2008 to 2019 by STATA. The horizontal axis stands for time, the vertical axis for the number of green patent applications, the dashed line for heavy polluters, the solid line for non-heavy polluters, and 2012 is the year of policy intervention. It can be seen that before the implementation, heavy polluters and non-heavy polluters basically maintain the same trend, while the difference between them becomes significantly larger after the implementation. Therefore, the parallel trend assumption is basically satisfied.

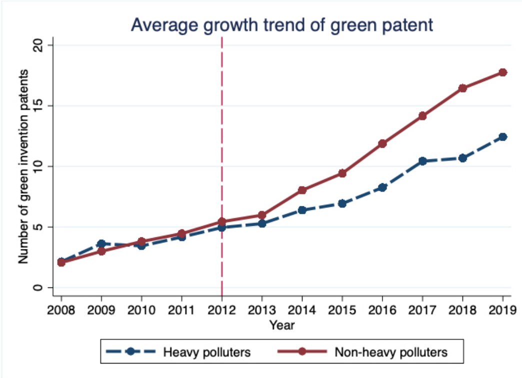

Figure 1. Parallel trend test

4.3 DID Test Results and Analysis

The results of the regressions on the constructed DID model are shown in Table 3. The models are all regressions obtained with two-way fixed effects of enterprises and time. The coefficient of Time×Treat in column (1) is -2.643 without adding control variables and is significant at 5% confidence level, indicating that the green innovation of heavy polluters declines significantly after the implementation compared to non-heavy polluters. Column (2) is still estimated to be significantly negative at the 5% confidence level after adding control variables. Therefore, the implementation does not have the overall effect of promoting heavy polluters to increase their green innovation, but rather inhibits the green innovation. Column (3) is validated again by regression based on PSM-DID method. Firstly, Probit regressions are conducted to score the predicted values by corporate size (Size), asset-liability ratio (Lev), corporate age (Age), total assets growth rate (Growth), profit rate of asset (Roa), tangible assets ratio (Tang), and corporate value (Tq) as the characteristic variables for the control and experimental groups. Then Nearest Neighbors is used for one-to-one matching. Finally, according to the regression conducted, the results are not significantly different from the above results and hypothesis H1 is verified.

Table 3. Regression results

Variables	(1)	(2)	(3)
Time × Treat	-2.643**	-2.380**	-2.560*
	(-2.20)	(-2.05)	(-1.86)
Constant	2.098***	-147.886***	-124.452***
	(3.61)	(-4.11)	(-3.46)
Control variables	No	Yes	Yes
Corporate fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
N	8,076	8,076	4,877
R^2	0.098	0.117	0.111

4.4 Heterogeneity Analysis

4.4.1 Patent Heterogeneity

To examine the differences in the types of corporate green patent, it is divided into green invention patent and green utility patent and then regressed separately. The results of column (1) and (2) are given in Table 4, and the coefficients of the interaction terms are 1.486 and 0.578 respectively. The former is significant at 5% confidence level, indicating that after the implementation, the number of green invention patent applications from heavy polluters decreases significantly compared with non-heavy polluters, while green utility patent is not significantly inhibited, which is consistent with hypothesis H2.

4.4.2 Property Heterogeneity

In the Chinese institutional context, SOE and non-SOEs face different financing constraints, and their responses to green innovation after the implementation may be different. This paper introduces property variables for group testing. The regression results are given in column (3) and (4) in Table 4. The coefficient of the interaction term is significantly negative in non-SOEs, while it is not significant in SOEs. It indicates that green innovation is significantly inhibited among non-SOE heavy polluters after the implementation. Moreover, non-SOE heavy polluters face more severe financing constraints, and the implementation does not change the credit discrimination between SOEs and non-SOEs. Therefore, hypothesis H3 is supported.

4.4.3 Regional Heterogeneity

China is a vast country with large differences in the financial market between regions, so the financing constraints faced by enterprises are different and the effect of green credit policy will be affected. Although the green credit policy brings financing constraints to heavy polluters, it will be alleviated in the eastern region compared with those in the central and western region due to the higher financial development, and the financial constraints on enterprises to carry out green innovation will also be alleviated. The total sample is divided into two groups: eastern region and central and western region, according to the provinces where the enterprises are registered. Column (5) and (6) in Table 4 demonstrate the results of the regional grouping test, where the coefficient of the interaction term is significantly negative in the central and western region, but not in the eastern region. It indicates that after the implementation, the green innovation of heavy polluters is significantly inhibited in the central and western region compared to the eastern region, and hypothesis H4 is confirmed.

Table 4. Heterogeneity regression results

Variables	(1) (Green Invention)	(2) (Green Utility)	(3) (SOE)	(4) (non-SOE)	(5) (Eastern Region)	(6) (Central and Western Region)
Time × Treat	-1.486**	-0.578	-2.569	-3.044**	-1.610	-3.077**
	(-2.27)	(-1.13)	(-1.46)	(-2.59)	(-0.96)	(-2.20)
Constant	-75.988***	-67.107***	-189.403***	-157.077***	-185.109***	-74.970*
	(-4.01)	(-4.27)	(-3.10)	(-3.25)	(-3.63)	(-1.82)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Corporate fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	8,076	8,076	4,652	3,424	5,462	2,614
R^2	0.101	0.121	0.146	0.103	0.122	0.141

5. Robustness Test

Previously, this paper has conducted a preliminary robustness test by parallel trend test and propensity score matching. To ensure that the findings are more reliable and not caused by other factors, this paper chooses to conduct a placebo test on the sample to ensure that the experimental and control groups are not significantly different before the implementation, thus identifying that the policy is the only factor leading to the findings. In this paper, we advance the time and test the sample before the event. Assuming that the time is 2010, we select the data from 2009 to 2011, with a value of 0 in 2009 and a value of 1 in both 2010 and 2011, and then comes the regression. The results in Table 6 show that the coefficient of the interaction term is not significant, indicating that Guidelines is the only factor that influences the corporate green innovation, verifying the validity of the research results again.

Table 5. Placebo Test

Variable	(1)	(2)
Time × Treat	-0.976	-0.898
	(-1.34)	(-1.33)
Constant	3.236***	-34.117
	(16.12)	(-1.03)
Control variables	No	Yes
Corporate fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
N	2,019	2,019
R^2	0.013	0.026

6. Conclusion and Insights

6.1 Conclusion

Based on the patent data of A-share listed companies in Shanghai and Shenzhen from 2008 to 2019, this paper uses a DID model to test the effect of green credit policy on green innovation of heavy polluters. The empirical study finds that compared with non-heavy polluters, the green credit policy significantly inhibits the green innovation of heavy polluters and fails to exert the Porter effect. Meanwhile, it further examines the heterogeneous effects from three aspects including patent type, enterprise property and region on the policy effects. The findings are as follows: Firstly, compared with green utility patent, green credit policy significantly inhibits green invention patent R&D output of heavy polluters with strategic innovation. Secondly, compared with SOEs, green credit policy significantly inhibits green innovation of non-SOE heavy polluters. Thirdly, compared with the eastern region, heavy polluters in the central and western region are more significantly inhibited by policy.

6.2 Insights

Green finance aims to enhance green economic development, which is not supposed to inhibit the development of heavy polluters but to guide the flow of funds to green environmental protection, and promote the transformation of heavy polluters to green innovation. The above empirical results show that green credit as a green financial policy significantly inhibits the green innovation of heavy polluters and does not exert the Porter effect. Based on the empirical results, this paper proposes the following policy recommendations.

(1) For the government, it is expected to improve the green credit policy system by formulating and introducing corresponding policies to assist green credit. At the same time, a perfect green rating standard for enterprises should be regulated to distinguish the greenness of enterprises and provide an evaluation basis for BFIs. In addition, it is suggested that the relevant departments are urged to publish a list of green patents as soon as possible so that BFIs may carry out green credit evaluation.

(2) For BFIs, they are supposed to overcome the shackles of traditional financial discrimination and stop focusing on the enterprise property. Instead, corporate green innovation should be attached importance to with more financial resources. At the same time, it is also necessary to reasonably control the loan threshold instead of unilaterally raising the threshold for heavy polluters, and vigorously support the heavy polluters that are willing to engage in green innovation and transformation. In addition, the flow of green credit funds should be monitored to ensure that the funds are earmarked for the promotion of the corporate green development.

(3) For enterprises, they should actively respond to the implementation of green policies and take the initiative to undertake environmental and social responsibility for green innovation and green transformation. Besides, they are expected to cooperate with BFIs to actively disclose their own environmental and social responsibility information to reduce the information asymmetry of green credit. Enterprises shall also seek substantive green innovation instead of policy support only for their own interests and green strategic innovation with less effect. In addition, enterprises must expand their financing channels. They are expected to strive for financial capitals and take full advantage of the capital market to conduct green innovation to speed up their green transformation.

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