The Impact of Green Credit Policies on Green Innovation in Heavily Polluting Firms: Evidence from China

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Abstract: Based on balanced panel data of listed companies from 2007-2017, this paper investigates the causal relationship between green credit policy and green innovation of heavily polluting enterprises. It finds that green credit policies can significantly promote green innovation among heavily polluting firms and that R&D investment mediates the relationship between the two, a finding that passes a series of robustness tests.

1.Introduction

Since its reform and opening up, China has made significant breakthroughs in economic development, but has caused enormous damage to the ecological environment. China has repeatedly emphasised its "3060" plan, which aims to control carbon emissions at their peak by 2030 and achieve carbon neutrality by 2060. To this end, China has developed a number of policies to reduce emissions, for example through economic restructuring or by investing more in pollution treatment technologies. However, measures such as these are end-of-pipe treatment tools that may come at a huge economic cost, and some financial means are indispensable to make substantial improvements to the ecological environment.

Green credit policies are one of the important financial instruments in the control of environmental pollution. In order to control the pollutants emitted by enterprises, the Chinese government has introduced a series of green credit policies, the most representative of which is the Green Credit Guidelines (hereinafter referred to as "the Guidelines") promulgated in 2012. The principle of green credit policies such as the Guidelines can be understood as follows: in the process of credit placement, financial institutions that lend money need to strictly control the polluting projects or some polluting enterprises carried out by enterprises, while clean projects or clean enterprises should be supported with more funds, so as to achieve the purpose of green talk allocation in loan placement. Under this theoretical framework, heavy polluting enterprises have to make green innovations in order to achieve green transformation if they want to obtain more credit funds. Green credit business is also growing rapidly in China, with data showing that the balance of green credit provided by 21 large Chinese banks grew from RMB 4.90 trillion at the end of June 2013 to RMB 10.6 trillion at the end of June 2019, accounting for 9.6% of the total loans provided by these banks. In addition, with the development of green credit business, academics are increasingly concerned about whether green credit policies can play their role in facilitating green innovation by heavy polluters.

2.Literature Review

The concept of green innovation was introduced by Braun et al. [1], who defined it as technological innovations that reduce environmental pollution and improve ecological conditions. James [2] argued that green innovation not only aims to minimize negative environmental impacts but also contributes to enhancing the overall value of businesses. Although different scholars have varied definitions of green innovation, the current understanding encompasses both technological advancements and the environmental benefits resulting from these innovations, distinguishing green innovation from general innovation.

Regarding the impact of environmental regulations on firms' green innovation, existing research presents two main perspectives. The first perspective, rooted in neoclassical economic theory, suggests that environmental regulations essentially internalize external environmental costs through imposing "Pigouvian taxes." This increases firms' costs, weakens their innovation capacity and willingness, and ultimately hampers green innovation. Several studies support this viewpoint [3, 4]. For instance, Stucki et al. [4] demonstrated that environmental regulations can crowd out innovation in green products.

The second perspective aligns with the Porter hypothesis, which is the focus of this study. This hypothesis posits that well-designed environmental regulations can stimulate innovation, thereby compensating for additional compliance costs and creating a win-win situation for the economy and the environment [5]. Existing literature primarily employs environmental indicators such as pollution emissions and pollution abatement costs to measure the regulatory effectiveness of environmental regulations [6, 7]. For example, Berrone et al. [6], using publicly traded data from polluting industries in the United States, found that regulatory pressure resulting from environmental regulations can trigger green

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innovation. However, recent research has also identified a U-shaped relationship between environmental regulations and firms' innovation, indicating a threshold effect where the promotion of green innovation by environmental regulations exhibits certain limitations [8].

3.Research hypothesis

3.1. Green Credit and Green Innovation

Green credit policies influence the green innovation of heavily polluting enterprises through two main channels. Firstly, green credit policies mainly guide heavy polluting enterprises to green innovation through the green allocation of funds. Specifically, when a firm emits more pollutants externally, it faces higher financing costs and may also incur corresponding environmental penalty costs. Conversely, when the environmental performance of a company is better, it has access to more credit financing, and the corresponding financing costs are lower and more favourable to investors. It can be seen that in the context of the implementation of the Guidelines, heavy polluters are more willing to transform themselves into environmentally friendly enterprises by relying on green technological innovation. Secondly, green credit policies can increase the legitimacy incentives of heavily polluting enterprises, which in turn can promote green innovation among medium-polluting enterprises. Specifically, in China, there is an increasing emphasis on corporate environmental awareness, more information on environmental performance will appear in major data reports, and the amount of credit available will influence how favourably investors and other stakeholders view a company. As a result, firms will invest more in green innovation. Based on the above analysis, the first hypothesis is formulated in this paper:

H1: Green credit policies can facilitate green innovation by heavy polluters.

3.2. The mediating role of R&D inputs

The development of enterprises cannot be achieved without the support of capital, and by the same token, the green innovation of enterprises cannot be achieved without the investment of R&D capital. The implementation of GCP will increase the financing cost of enterprises, and in order to reduce the financing cost, enterprises need to make green transformation, and green transformation cannot be achieved without the increase of R&D investment. When enterprises have more funds to invest in R&D, they will have more opportunities to carry out green innovation. Therefore, this paper proposes a second hypothesis:

H2: R&D investment has a mediating role between GCP and green innovation of heavy polluting firms.

4.Variable selection and model setting

This paper selects Chinese A-share listed companies from 2007-2017 for the study. The innovation data consisted of the number of green patents obtained from CNRDS, while all other data were obtained from Guotaian. After excluding relevant non-conforming data, the final balanced panel data consisting of 9,757 annual observations was obtained. In addition, 1% and 99% tailing was applied to all continuous variables.

4.1. Variable definitions

(1) Explanatory variable: Green technology innovation (Patent), which measures a firm's green innovation performance as the logarithm of the sum of the number of green patents obtained and 1.

(2) Explanatory variable: cross product of GCP (Post) and industry attributes (Treated) (Treated×post). If the sample is before 2012, Post = 0, otherwise Post = 1. If the firm is a heavy polluter, Treated = 1, otherwise Treated = 0.

(3) Mediating variable: R&D investment (RD). The logarithm of RD investment is used to measure the intensity of R&D on innovative technologies.

(4) Control variables: Considering that other factors at the firm level may have potential influence on firms' green innovation, firm size (Lnsize), firm age (Lnsize), gearing (Lev), and revenue growth rate (Growth) were selected as control variables, while controlling for industry fixed effects and year fixed effects.

4.2. Model determination

A double difference model was constructed (Model 1) to examine the impact of green credit on green innovation.

In (1), i and t denote firm and year, respectively, Controlsi,t is a set of control variables, λt is a year fixed effect, δt is an industry fixed effect, and εi,t is a random error term.In addition, to test the mediating effect of R&D inputs, the following model was developed based on (1) with reference to WEN, et al. [9]:

$$Ln(1+Patent)_{i,t+1} = \beta_0 + \beta_1 \times Treated_i + \beta_2 Treated_i \times Post_t + \beta_3 Post_t + \beta_4 Controls_{i,t} + \lambda_t + \delta_i + \varepsilon_{i,t} \quad (1)$$

$$RD_{i,t} = \varphi_0 + \varphi_1 Treated_i + \varphi_2 Treated_i \times Post_t + \varphi_3 Post_t + \varphi_4 Controls_{i,t} + \lambda_t + \delta_i + \varepsilon_{i,t} \quad (2)$$

$$Ln(1+Patent)_{i,t+1} = \partial_0 + \theta RD_{i,t} + \partial_1 Treated_i + \partial_2 Treated_i \times Post_t + \partial_3 Post_t + \partial_4 Controls_{i,t} + \lambda_t + \delta_t + \varepsilon_{i,t} \quad (3)$$

5.Empirical Results and Analysis

5.1. Baseline regression results

Table 1 reports the regression results for model (1). The results show that in both columns (1) and (3), the regression coefficients of Treated×Post were not significant before the inclusion of control variables, but after the inclusion of control variables, the regression coefficients are both significant at the 1% level as evidenced by a coefficient of 0.178 after controlling for industry fixed effects and year fixed effects, which can indicate that after the implementation of the GCP, heavy The coefficient is 0.178 after controlling for industry fixed effects and year fixed effects. The regression results show that the GCP significantly increased the green innovation capability of the heavily polluting enterprises, and research hypothesis 1 was adopted.

Table 1 Main effects regression results

Variables	Green Technology Innovation (GTI)			
	(1)	(2)	(3)	(4)
Treated×Post	0.127	0.162***	0.128	0.178***
	(0.028)	(0.023)	(0.027)	(0.026)
Constant	0.410	0.645***	0.454**	0.153**
	(0.038)	(0.054)	(0.227)	(0.216)
Control variables	NO	YES	NO	YES
Industry FE	NO	NO	YES	YES
Year FE	NO	NO	YES	YES
N	9757	9757	9757	9757
R^2	0.123	0.256	0.265	0.211

Note: Two-tailed test t-statistics in brackets; *, ** and *** denote significant at 10%, 5% and 1% confidence levels respectively. Same as below.

6. Analysis of impact mechanisms

Table 2 reports the regression results of models (1)-(3). It can be found that the regression coefficient of Treated×Post in column (1) is significantly positive at the 1% level, indicating that the green credit policy can significantly promote enterprises to increase their R&D investment funds. Meanwhile, the regression coefficients of Treated×Post and RD in column (2) are both significantly positive at the 1% level, thus indicating that R&D investment has a partial mediating effect in this causal relationship. Based on the results of the above analysis, it can be shipped that green credit policy can increase the R&D investment of enterprises and thus improve the green innovation capacity, i.e. the mediating effect of R&D investment is verified and hypothesis 2 is passed.

Table 2 Regression results on the mediating role of R&D investment

Variables	R&D	GTI
	(1)	(2)
Treated×Post	0.578***	0.167***
	(0.142)	(0.029)
RD		0.009***
		(0.001)
Constant	3.213**	0.101
	(1.433)	(0.234)
Control variables	YES	YES
Industry FE/Year FE	YES	YES
N	9757	9757
R2	0.317	0.243

7.Robustness test

7.1. Parallel trend test

A prerequisite for using the double difference method is that the experimental and control groups need to meet the parallel trend test, i.e. the two data groups need to have the same trend of change prior to the implementation of the policy to ensure that the implementation of the Guidelines is the only factor causing the difference between them. Referring to Bertrand, et al. [10], the parallel trend test was conducted using 2011 as the base year. As shown in Figure 1, there was no significant difference in the green innovation capacity between the two before the implementation of the policy, and after the implementation of the policy, there was a significant difference in the green innovation capacity of the experimental group with an overall positive result. Therefore, the robustness of Hypothesis 1 can also be tentatively tested.

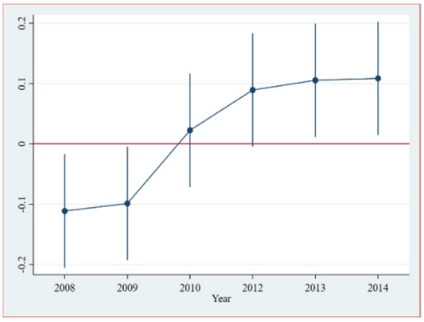

Figure 1 Parallel trend test

7.2. Placebo test

To exclude the effect of random factors and omitted variables, a placebo test was conducted by referring to La Ferrara, et al. [11] and Li, et al. [12] to randomly generate the policy implementation time and randomly screen out the heavily polluting enterprises, and the process was repeated 500 times to plot the distribution of the estimated coefficients of Treated×Post. It can be found that the estimated coefficients of the double difference are mainly distributed around 0 and most of them are insignificant below 10%, and the results of the baseline regression are not included in the test results, so the effect of random factors and omitted variables can be excluded and the conclusion of this paper remains significant.

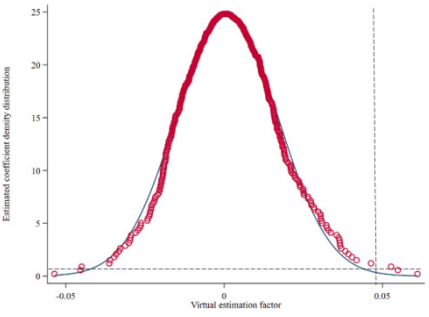

Figure 2 Placebo test

7.3. Tobit Model Examination

Considering that the green patent data used in this study has a minimum value of 0 and exhibits clear left-censoring characteristics, we re-examine the baseline regression using the Tobit model. Table 3, Column (1), reports the regression results of the Tobit model, indicating that the coefficient of the interaction term Treated×Post remains significantly positive at the 1% confidence interval. This regression result is consistent with the main regression findings, further supporting the primary research conclusions of this study.

7.4. Variation in Observation Period

To mitigate potential random errors associated with a single observation period, we replace the observation periods for the treatment group and control group with 2008-2016, 2009-2015, and 2010-2014, respectively. We then employ the main regression model to analyze the impact of the "Guidelines" on green innovation among heavily polluting firms. Table 3, Columns (2)-(4), present the regression results for different observation periods. It can be observed that across various observation periods, the coefficient of the interaction term Treated×Post remains significantly positive at the 1% confidence level. This indicates that the impact of the "Guidelines" policy on green innovation performance among heavily polluting firms remains fundamentally unchanged across different sample observation periods, further confirming the robustness of the results.

Table 3 Main effects regression results

Variables	Green Technology Innovation (GTI)			
	(1)	(2)	(3)	(4)
Treated×Post	0.245***	0.156***	0.135	0.167***
	(0.08)	(0.053)	(0.037)	(0.046)
Constant	0.583***	0.645***	0.454**	0.153**
	(0.138)	(0.542)	(0.284)	(0.258)
Control variables	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
N	9757	7043	4863	3645
R^2	0.133	0.246	0.267	0.2

8.Conclusions and insights

Using Chinese A-share listed companies from 2007-2017 as the research sample, this paper empirically finds that green credit policy can promote green innovation of heavy polluting enterprises by increasing their R&D investment, and the findings pass robustness tests such as parallel trend test and placebo test. It also reveals that the government should continuously improve green credit as an environment-friendly environmental regulation, increase enterprises' willingness to green transformation, and actively mobilize market forces to reduce sloppy development at the cost of environmental damage.

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