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Green Credit Policies and Enterprise Technology Innovation -- An Empirical Study from China

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Abstract

This paper makes use of the enactment of the Green Credit Guidelines as a quasi-natural experiment and builds a difference-in-differences (DID) model to identify the influence of green credit policies on technological innovation of heavy–polluting enterprises and its impact mechanism. Using the data of A-share listed enterprises from 2010 to 2019. The findings include that technological innovation of heavily polluted enterprises can be inhibited significantly by green credit policy.

Keywords

Green Credit Policy; Technological Innovation; Heavily Polluting Enterprises.

1. Introduction

Technological innovation is the fundamental force for enterprises to achieve high-quality development[1], and has an obvious positive effect on industrial pollution control[2]. Green financial policies serve both capital allocation and environmental regulation functions[3]and help promote the development of a low-carbon economy[4]. The influence of the Green Credit Guidelines issued by CBRC (China Banking Regulatory Commission) in 2012. Green credit policy is a source of fresh water to stimulate enterprises' green innovation.

Green credit policy differs from traditional environmental regulation policies because it continuously guides enterprises to reduce their behavior in polluting the environment. [7][8]Green credit plays an important role in promoting the green and low-carbon development of the economy and assisting enterprises in green innovation. Existing literature focuses on the influence of green credit policies on corporate green innovation[7][8], investment efficiency[9], and corporate financing costs[10][11]. Compared to light–polluting enterprises with low emissions, heavy–polluting enterprises can cause serious pollution to the environment. Therefore, this paper combines green credit policies to identify their influence and mechanism of action on the technological innovation of heavy–polluting enterprises.

2. Literature Review

There are two main views on the micro effects: one view is that green credit policy can improve the environmental condition of micro–enterprises. Green credit reduces new loans to highly polluting enterprises[12][13], significantly increases the investment in the environmental treatment of heavily polluting enterprises[14], and has a significant influence to the innovation performance of environmentally friendly enterprises [15]. Another view is that green credit policies have a negative influence on the environmental performance of micro–enterprises. Green credit policies can impose constraints on the financing channels of heavily polluting enterprises[10][16].

There are both external and internal factors that influence technological innovation in enterprises. On the one hand, technological innovation of heavily polluting enterprises can be promoted by digital transformation from the external factors[1]. On the other hand, restricted

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financing constraints can provide sufficient financial support for technological innovation activities, thus inhibiting enterprises technological innovation, and overly strong environmental regulations, as a means of environmental regulation, can also inhibit technological innovation [17]. Enterprises technological innovation can be inhibited by endogenous financing constraints[18]and two types of agency problems of firms from the internal factors [19][20].

3. Theoretical Analysis and Research Hypothesis

Green credit policy has a dual role in environmental regulation and resource allocation. Unlike mandatory environmental regulation policies, green credit can encourage and impose credit constraints on their inappropriate behavior. On the one hand, the cost effect shows that pollution control and production costs of enterprises can be improved by green credit policies, and enterprises will reduce their investment in technological innovation projects due to the increase in costs. On the other hand, the Porter hypothesis effect shows that appropriate green credit policies can urge enterprises to innovate and achieve technological progress, which can offset the negative impact brought by the increase in costs.

Technological innovation activities are inherently risky, with long payback periods and high uncertainty of returns, and enterprises need significant support to actively pursue technological innovation.

It is assumed that in each production cycle, the firm needs to pay a $d_i \in (0,1)$ proportion of its innovation investment through credit financing, and d_i denotes the firm's external financing needs. In this paper, it is assumed that the firm's external financing needs d_i are given. Firms are assumed to be required to pay off their loans at the end of each period so that the green credit constraint can directly affect firms' innovation investment decisions. The profit maximization problem faced by the firm under the green credit constraint is:

$$max\left(\frac{p^{1-\sigma}}{R}q_i\right)^{-\frac{1}{\sigma}}q_i-\frac{c_i\varphi q_i^2}{r_i}-\varphi r_i-m^n\left(T_e^{\beta}f\right) \tag{1}$$

$$\text{s.t.}\ \frac{1}{Te}\left[\left(\frac{p^{1-\sigma}}{R}q_i\right)^{-\frac{1}{\sigma}}q_i-\frac{c_i\varphi q_i^2}{r_i}-(1-d_1)\varphi\gamma_i-m^n\left(T_e^{\beta}f\right)\right]\geq \varphi d_i\gamma_i \tag{2}$$

In this paper, we only discuss the case where budget constraint (2) is tight, and where firms are constrained by green credit policies. Solving the profit maximization problem with optimal investment in innovation through the zero-profit condition, the market clearing condition, and the free entry condition. Optimal Innovation Investment[错误!未找到引用源。]:

$$r_i^*=\left(\frac{\sigma-1}{2\sigma}\right)^{\sigma}\frac{R}{P^{1-\sigma}}\frac{1}{\sqrt{1+\Delta}^{\sigma+1}}\frac{1}{\sqrt{c_i}^{\sigma-1}}\frac{1}{\varphi^{\sigma}} \tag{3}$$

Productivity thresholds:

$$\left(\varphi^*\right)^{\theta}=\frac{\theta}{\varphi-1}\frac{f_e}{f}\left(\frac{f}{R}\right)^{\frac{\eta}{\eta+1}}\left(\frac{\theta-\sigma+1}{\theta}\right)^{\frac{1}{\eta+1}}Te^{-\frac{\beta}{\eta+1}}\left[1-\frac{2+\Delta}{1+\Delta}-\frac{\sigma-1}{2\sigma}\right]^{-\frac{\eta}{\eta+1}} \tag{4}$$

Corporate profitability:

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$$PR(\varphi) = \frac{\left[1-\frac{2+\Delta\sigma-1}{1+\Delta 2\sigma}\right]\cdot r(\varphi)-M^{\eta}\left(T_e^{\beta}f\right)}{r(\varphi)} = \left(1-\frac{2+\Delta}{1+\Delta}\frac{\sigma-1}{2\sigma}\right)\left(1-\frac{r(\varphi^*)}{\gamma(\varphi)}\right) \quad (5)$$

The ratio of firms' market shares:

$$\frac{\gamma(\varphi_1)}{\gamma(\varphi_2)} = \left(\frac{\varphi_1}{\varphi_2}\right)^{1-\sigma} \quad (6)$$

$\Delta = d_i\lambda(Te-1) / (1+\lambda)$，$\lambda$ denotes the Lagrange multiplier, and given $d_i \in (0,1)$ and $\lambda > 0$, then $\partial\Delta/\partial T_e > 0$ and $T_e \geq 1$. $1 / Te$ is used to denote the degree of credit constraint of the green credit policy, the lower $1 / Te$, the tighter the credit constraint.

Given the firm's initial productivityφ, the demand for credit d_i, $T_e \geq 1 + \frac{2}{d(\sigma-1)}\left[1-\left(\frac{\varphi}{\beta^*}\right)^{(\varphi-1)}\right]$.

Analyzing how green credit policy affects innovation investment in polluting firms is obtained by taking the partial derivative of equation (3) concerning T_e:

$$\frac{\partial\gamma_i^*}{\partial Te} = \left(\frac{\sigma-1}{2\sigma}\right)^{\sigma}\frac{R}{P^{1-\sigma}}\frac{1}{\varphi^{\sigma}}\left[\frac{1-\sigma}{2}\frac{1}{\sqrt{c_i}^{\sigma+1}\sqrt{1+\Delta}}\frac{1}{\sigma+1}\frac{\partial c_i}{\partial Te} - \frac{1+\sigma}{2}\frac{1}{\sqrt{c_i}^{\sigma-1}}\frac{1}{\sqrt{1+\Delta}^{\sigma+3}}\frac{\partial\Delta}{\partial Te}\right] < 0 \quad (7)$$

Equation (7) shows that at the firm level, green credit policy affects firms' investment in innovation through at least two types of pathways, follow-the-cost effect and credit constraint effect. $\frac{1-\sigma}{2}\frac{1}{\sqrt{c_i}^{\sigma+1}\sqrt{1+\Delta}}\frac{1}{\sigma+1}\frac{\partial c_i}{\partial Te}$ denotes the cost of compliance effect, whose value is less than zero, and $\frac{1+\sigma}{2}\frac{1}{\sqrt{c_i}^{\sigma-1}}\frac{1}{\sqrt{1+\Delta}^{\sigma+3}}\frac{\partial\Delta}{\partial Te}$ denotes the credit constraint effect, whose value is also less than zero. It can be concluded that it mainly inhibits the technological innovation of heavy-polluting enterprises by following the double effects of the cost effect and credit constraint effect superimposed.

Continuous innovation in technology is important for environmental protection, and advanced technology can reduce environmentally damaging activities and drive business development. In summary, we propose the following:

Hypotheses 1: Technological innovation of heavily polluted enterprises can be constricted by the enactment of green credit policies.

Hypotheses 2: Technological innovation of heavily polluted enterprises can be promoted by the enactment of green credit policies.

4. Model Construction

This paper uses A-share listed enterprises in Shanghai and Shenzhen from 2010 to 2019 as the original sample and classifies 14 industries such as pharmaceuticals and chemicals as heavy polluting industries. According to the classification criteria of the "List of Listed Companies' Environmental Protection Verification Industry Classification Management" issued by the former Ministry of Environmental Protection in 2008, industries such as metallurgy and cement belong to the heavy polluting industries. To make the research results more accurate, this paper also does the following screening of the sample: (1) exclude ST (special treatment) and PT (particular transfer) samples. (2) exclude samples with missing data. (3) do a 1% before and after tailing of the continuous variables. Finally, 440 listed companies with a total of 4400 data were obtained. The data are obtained from CSMAR (China Stock Market & Accounting Research Database) database.

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The following model can be constructed to identify the role of green credit policies on enterprises technological innovation.

$$Rd_{it} = \alpha_0 + \alpha_1 Treat_i + \alpha_2 Post_t + \alpha_3 Treat_i \times Post_t + \alpha_4 X_{it} + Firm_i + Year_t + Industry_i + \varepsilon_{it} \quad (8)$$

Equation (8) is the baseline regression model, Rd_{it} represents enterprises technological innovation, X_{it} represents the control variable, $Firm_i$ represents the enterprises fixed effects, $Year_t$ represents the time fixed effects, $Industry_i$ represents the industry fixed effects, and ε_{it} represents the random error term. $Treat_i \times Post_t$ is the core explanatory variable whose coefficient indicates the effect of green credit policy on technological innovation of heavily polluted enterprises.

Table 1 is the results of descriptive statistics of the variables. The mean value of Rd is 0.036, indicating that heavily polluting enterprises have low technological innovation and do not take the initiative to develop technological innovation projects. The standard deviation of Rd is 0.031, indicating that the enthusiasm to develop technological innovation projects varies from enterprise to enterprise, and the difference is large. According to the multicollinearity test, the maximum value of VIF (Variance Inflation Factor) is 2.46 and the minimum value is 1.12, which is much smaller than the critical value of 10, and the problem of multicollinearity is not serious among the variables.

Table 1. Descriptive statistics

Variables	N	Mean	Sd	Min	Max
Rd	4400	0.036	0.031	0.000	0.169
Treat	4400	0.841	0.366	0.000	1.000
Post	4400	0.800	0.400	0.000	1.000
Growth	4400	0.167	0.333	–0.426	42.071
Lev	4400	0.417	0.190	0.055	0.854
Ros	4400	0.070	0.133	–0.542	0.465
Size	4400	22.13	1.128	19.90	25.26
Cashflow	4400	0.018	0.042	–0.034	0.195
ATO	4400	0.193	0.402	0.000	2.039
Age	4400	2.248	0.667	0.000	3.219
Board	4400	0.185	0.191	0.000	0.571

5. Empirical Results and Analysis

5.1. Baseline Regression

Table 2 represents the results of the baseline regressions. The regression coefficient of the variable Treat×Post is 0.0294 when no control variables are introduced, and the regression coefficient of the variable Treat×Post is 0.0275 after the introduction of control variables, and both are significant. Green credit policy inhibits technological innovation of heavily polluted enterprises at the 1% significant level, hypothesis 1 holds and hypothesis 2 does not hold. The reason probably is that green credit policies do not have mandatory constraints and lack penalties, resulting in heavily polluting enterprises being reluctant to actively engage in risky technological innovation, whether they lack funds or have sufficient funds.

Some scholars have found that gender diversity on the board of directors significantly enhances the quantity and quality of green innovation, while irrational enterprises governance mechanisms as well as managerial power inhibit heavily polluting enterprises from engaging

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in green technological innovation. This is different from the mechanism by which green credit policy affects enterprise technological innovation, suggesting that the internal factors of enterprises also have an influence on enterprise technological innovation.

From the existing results, domestic scholars in the study of the impact of green credit policy on the technology innovation of heavy pollution enterprises, usually do a deeper study on the technology innovation of enterprises, mainly focusing on economic growth, industrial structure, bank business performance, enterprises investment and financing and enterprises social responsibility. Foreign scholars study the influence of green credit policy on the technological innovation of heavy pollution enterprises, they mainly analyze it through the aspect of credit capital. It is generally believed that it will reduce the credit capital of enterprises, and then the technological innovation of enterprises can be inhibited.

Table 2. Baseline regression analysis

Variables	Rd	Rd
	(1)	(2)
Treat×Post	−0.0294***	−0.0275***
	(0.00186)	(0.00179)
Growth		−0.00194
		(0.00134)
Lev		−0.0207***
		(0.00372)
Ros		−0.00631
		(0.00585)
Size		0.000284
		(0.000469)
ATO		−0.00360***
		(0.00123)
Cashflow		−0.0198
		(0.0129)
Age		−0.00551***
		(0.000771)
Board		0.0192***
		(0.00306)
Corporate fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Constant	0.0231***	0.0342***
	(0.000935)	(0.00919)
Observations	4400	4400
R^2-squared	0.136	0.210

5.2. Triple Difference Model

A possible problem with the estimation using a double difference model is that there may be contemporaneous relevant policies other than the green credit policy that have an influence on the estimation results. Therefore, the difference in the external financing needs of firms (Credit) is chosen as the third double difference variable to generate the experimental and control groups that are not affected by it.

The main reason is that enterprises with low external financing needs are not affected by the green credit policy or the degree of influence is small, the difference between the experimental

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group and the control group will only originate from other policies, and then the difference between the original experimental group and the control group is subtracted from the difference between the newly generated experimental group and the control group to get the net effect of the green credit policy. Among them, the difference in the external financing needs of enterprises is expressed by "net accounts receivable/total assets", and the value of this variable is divided into three quadrilles, with enterprises below the 1/3 quarterly being taken as 1, enterprises above the 1/3 quarterly being taken as 0, and other enterprises are not included in the sample. The triple difference model is constructed as shown in equation (9).

$$Rd_{it}=\alpha_0+\alpha_1 Treat_i\times Post_t\times Credit_f+\alpha_2 Treat_i\times Post_t+\alpha_3 Treat_i\times Credit_f+\alpha_4 Post_t\times Credit_f \alpha_5 X_{it}+Firm_i+Year_t+Industry_i+\varepsilon_{it} \quad (9)$$

In this paper, we focus on the regression coefficient α_1, if $\alpha_1>0$, the result of the dual differencing model may not be robust, if $\alpha_1<0$, it proves that the result of the dual differencing model is robust, the regression result of the triple differencing model is shown in Table 3.

Table 3. Triple difference model regression results

Variables	Rd	Rd
	(1)	(2)
Treat×Post×Credit	−0.00525***	−0.00320**
	(0.00115)	(0.00128)
Treat×Post	−0.0256***	−0.0253***
	(0.00206)	(0.00210)
Growth		−0.00137
		(0.00164)
Lev		−0.0278***
		(0.00454)
Ros		−0.0156**
		(0.00651)
Size		0.000806
		(0.000543)
ATO		−0.00480***
		(0.00154)
Cashflow		−0.0164
		(0.0158)
Age		−0.00464***
		(0.00107)
Board		0.00768**
		(0.00374)
Corporate fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Constant	0.0635***	0.0678***
	(0.00180)	(0.0109)
Observations	3520	3520
R^2-squared	0.123	0.173

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The regression coefficient of the variable Treat×Post×Credit is −0.00525 when no control variables are introduced, and the regression coefficient of the variable Treat×Post×Credit is −0.00320 after the introduction of control variables, and both are significant.

6. Robustness Tests

So as to strip the interference of such factors on enterprises technology innovation, the method of random sampling in the full sample is adopted to solve this problem. The placebo test originally originated in psychology and is a counter factual test. In economics the placebo test is often a test of a policy, hypothetically testing whether or not there is an effect on that policy if it does not exist.

This paper reconstructs the experimental and control groups and takes the year before the enactment of the policy as the baseline period, conducts regression analysis according to model (1) and repeats the process 500 times randomly, Figure 3 shows the distribution of the spurious estimated coefficients. The estimated coefficients approximately obey a normal distribution, and the baseline estimated coefficient is 0.0275, indicating that omitted variables do not inhibit technological innovation of heavily polluted enterprises, and it is the enactment of green credit policy that leads to the weakening of technological innovation in enterprises.

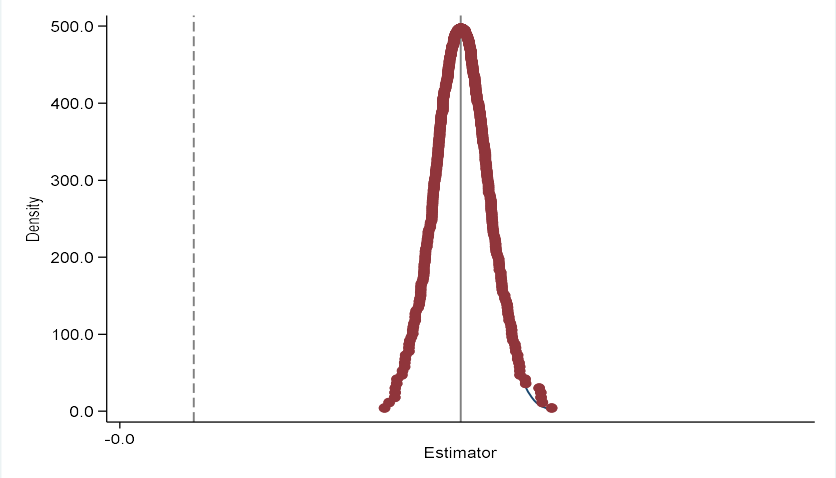

Figure 1. Distribution of estimated coefficients

7. Conclusion

This paper investigates the influence and mechanism of green credit policy on technological innovation of heavily polluted enterprises using the double difference method with the panel data of Shanghai and Shenzhen A-share listed enterprises in 2010–2019. The conclusions show that: green credit policy has an inhibitory effect on technological innovation of heavy–polluting enterprises after a series of entropy balance matching tests, replacement of explanatory variables and other, this conclusion is still highly robust.

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