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Can green credit policy stimulate firms' green investments?

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ABSTRACT

Green credit policy, a market-oriented green financial tool, aims to achieve simultaneous economic development and environmental protection. Utilizing china's 2012 green credit policy as a quasi-natural experiment, this paper employs a difference-in-differences method to explore its causal impact on Chinese firms' green investment behavior. The empirical results indicate that the green credit policy significantly stimulates the green investments of firms in pollution-intensive sectors compared to those in non-pollution-intensive sectors. This finding remains robust across various tests, including parallel trends, dynamic effects, confounding factors, and alternative methods. Furthermore, the green investment-induced effect is reinforced by the supplementary green credit policy introduced in 2018. The heterogeneity effect reveals that the green credit policy facilitates the green investments of firms with undisclosed environmental information. Additionally, the study finds that the green investment-induced effects are more pronounced among firms with soft financial constraints, limited access to government subsidies, state-owned firms, and larger sizes. These findings shed light on the crucial role of green finance policy in promoting green recovery, suggesting that the government should increase the provision of green credit in terms of quantity and scope.

1. Introduction

Climate change has aroused global concern for economic growth and green investment (Kotz et al., 2021). Green investment involves the expenditure and expenses from accumulated capital or funds for pollution control and environmental protection. Green investment is essential for the urgent global need to achieve carbon neutrality and sustainable development goals through green transformation (McCollum et al., 2013). China has set ambitious climate targets, aiming for a carbon peak by 2030 and carbon neutrality by 2060, necessitating significant investments in green projects and technology (Polzin & Sanders, 2020). Unfortunately, recent estimates indicate that China still requires an additional capital of 40.3 trillion to 123.4 trillion yuan between 2015 and 2030 to accomplish the green transformation goal. Additionally, an annual investment of 4 trillion yuan is needed for energy conservation, environmental protection, and clean energy initiatives. However, the government can only provide 10% of the required financial support, while the remaining 90% of green investment relies on the private sector. Fig. 1 illustrates the investment in environmental

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pollution governance. According to statistics, there has been a notable increase in environmental governance investment. However, there is still a decreasing proportion in relation to GDP. According to the statistics shown in Fig. 1, firms invested 106.389 billion yuan in environmental governance in 2020. Despite experiencing a significant increase of 40% compared to 2010, the percentage of environmental investment in relation to GDP is declining. This highlights the presence of a substantial funding gap for green investment in the private sector.

In recent years, the Chinese government has been consistently enhancing its support and regulatory measures for green finance, particularly by establishing a mechanism for the green credit market. Bank loans, as an indispensable source of firm financing, aim to reduce pollution by reallocating credit among companies (Chao et al., 2021). In 2012, the China Banking Regulatory Commission (CBRC, 2012) introduced the Green Credit Guidelines to facilitate green development by allocating resources to low-carbon, recycling, and ecological sectors. Subsequently, the "Green Finance Guidelines (Trial)" were released in 2014, providing definitions and requirements for green finance products, including green credit, green bonds, and green insurance. In 2016, the People's Bank of China issued the "Guidance on Establishing a Green Financial System", which standardized and classified financial instruments such as green bonds and green loans. To further strengthen the implementation of green credit, a supplementary green credit policy was introduced in 2018, incorporating green credit policies into the bank's performance evaluation. This necessitated banks to conduct self-evaluations of green credit from both quantitative and qualitative perspectives. The implementation of this work system is strictly enforced, with each bank required to provide comprehensive evidence and supporting documents during the self-evaluation process. China has emerged as one of the world's largest issuers of green credit, experiencing rapid growth in its green credit market in recent years. At the end of 2022, the outstanding balance of green loans from financial institutions in China exceeded 22 trillion yuan.

The green credit policy plays a crucial role in incentivizing firms operating in pollution-intensive sectors to engage in green investment. Broadly defined, the green credit policy is a market-based instrument that combines financial institution supervision with market incentives. Market-based environmental regulation encourages firms to make rational choices between costs and benefits and determine their green investment level through market incentives (Huang & Lei, 2021; Xie & Zou, 2021). Therefore, green credit is a kind of market-based environmental regulation, which provides more green loans by implementing preferential interest rates for green projects and encourages firms' green investment behaviors. Green credit internalizes some environmental costs of firms through change the relative financing costs. However, previous literatures about green credit policy mainly focuses on the impact of green credit policy on firms' economic and social effects (Sinha et al., 2021; Sun et al., 2019), such as bank competitiveness (Luo et al., 2021), firm performance (Luo et al., 2017; Yao et al., 2021), firm innovation (Hong et al., 2021; Hu et al., 2021; Zhang et al., 2021), and financial constraints (Yu et al., 2021; Zhang et al., 2020; Zhou et al., 2020). Some researchers explore the role of green credit policy in sustainable development from a regional perspective. They found that green credit policy contributes to fostering green development through the mitigation of sulfur dioxide and wastewater emissions, which can improve China's environmental quality overall (He et al., 2019; Zhang et al., 2021). Furtherly, Bai and Lin (2024) made the green credit, green investment and other indicators in a comprehensively framework to evaluate the green financial environment.

However, the relationship between green credit policy and firms' green investments behavior remains uncertain. As a significant policy tool in green finance, it is crucial to thoroughly examine whether the green credit policy has a positive guiding effect on firms' investments in environmentally friendly projects. Firstly, the green credit policy provides a market signal for green transformation, raising the question of whether it will encourage firms to make green decisions. Secondly, it is important to determine whether firms will actively promote green investment to expedite green transformation after obtaining green financing or whether there is a possibility of engaging in "greenwashing" behavior by utilizing the acquired funds for non-green investments. These questions necessitate

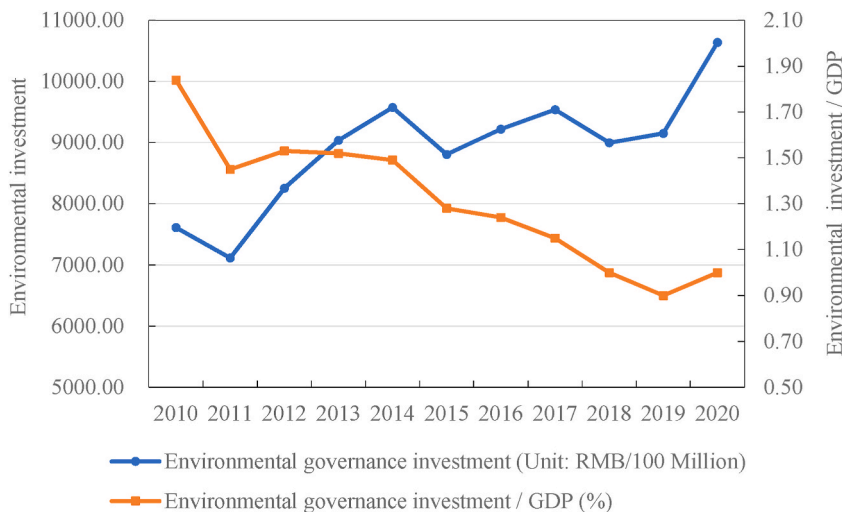


Fig. 1. Environmental pollution governance investment in China.

Note: The data comes from the China Ecological and Environmental Annual Statistical Report.

further exploration.

To address this research gap, this paper employs a difference-in-differences method to examine the impact of the green credit policy on the green investment behavior of Chinese firms. The implementation of the green credit policy in 2012 represents a significant milestone in China's green finance policy, signifying a transition to a new phase (Liu et al., 2021). It is also a widely recognized time point in current academic research of green credit policy (Wen et al., 2021). Therefore, we select China's green credit policy in 2012 as a quasi-natural experiment. Since green credit primarily impacts polluting firms involved in polluting projects, this paper considers high-polluting and energy-intensive firms as the treatment group and other firms as the control group for empirical testing.

This paper contributes to the existing literatures in two ways. First, we enrich the research on the relationship between green credit policies and firm's green investment in emerging market, evaluating and analyzing the effectiveness of market-based green credit policies in promoting environmentally friendly lending practices in China. Our impact mechanism research allows us to unlock the black box and explain how green credit incentivizes firms to make green investments. From the banks' point of view, we also reveal their concerns about how to stimulate firms' green behaviors effectively. Second, we have developed a framework that links government decision, firm behavior and green finance and investigated the driving forces and motivations of firms to make green investments compared to traditional investments. We discuss the impact of green credit policy on green investment from the perspective of environmental information disclosure, financing constraints, government subsidies and firm heterogeneity. The results provide new practical ideas for international society about how to stimulate social capital to participate in green development.

The remainder of this paper is organized as follows. Section 2 provides a literature review and develops hypotheses. Section 3 introduces the data source, variable construction, and empirical methodology. Section 4 presents the empirical results and robustness checks. Section 5 delves into further discussions on the mechanisms. Finally, Section 6 provides the conclusion, implications, limitations and future research opportunities.

2. Literature review and hypothesis development

2.1. Literature review

Green credit achieves a win-win situation between economic development and environmental protection through the rational allocation of credit resources (Zhou et al., 2020). Regarding environmental benefits, the green credit policy serves as an incentive for firms with positive environmental externalities. The green credit policy can enhance firms' pollution prevention efforts (Sun et al., 2019; Wang & Zhi, 2016). The green credit policy plays a crucial role in promoting investments in renewable energy (Zhang et al., 2021), inhibiting energy-intensive investments (Wang et al., 2020), and improving the high-efficiency utilization of energy (Song et al., 2021). Green credit policies also stimulate firms' green innovation (Hong et al., 2021; Hu et al., 2021), especially for highly polluting and energy-intensive firms (Zhang et al., 2022), leading to positive spillover effects in terms of knowledge and the environment (Rennings, 2000). Zhao et al. (2023) find that the investment-cash flow sensitivity of heavily polluting firms increases significantly after the implementation of the green credit policy.

Furthermore, the green credit policy can impose a "penalty effect" on firms with negative environmental externalities. Financial institutions may increase loan costs or even halt lending to polluting firms (Cui et al., 2021), compelling them to reduce production and investment (Zhang et al., 2021). Green credit policy increases the debt financing cost of polluting firms (Liu et al., 2019) and reduces the maturity date of their debts (Xu & Li, 2020), and further affect the cost of equity financing by changing the financial condition and information disclosure of firms (Zhang et al., 2022). As a result, the green credit policy curtails the performance of heavily polluting industries by limiting their access to financing sources, thus constituting a "penalty effect" (Yao et al., 2021).

Therefore, a green credit policy may affect green investment through incentives and penalties. Previous studies have identified motivations for firms to engage in environmental investment, such as cost savings, compliance with regulations, and enhancing corporate image (Maxwell & Decker, 2006). Strengthening environmental regulations allows the government to effectively guide firms towards investing in environmental technologies (Leiter et al., 2011), while also incentivizing private investment in green sectors (Huang & Lei, 2021). However, there is limited literature on the impact of green credit on firms' overall green investment, as most studies have focused exclusively on renewable energy investment (Bai et al., 2021; Ji & Zhang, 2019; Ng & Zheng, 2018), neglecting other areas.

2.2. Hypothesis development

The impact of a green credit policy on firms' green investment behavior remains a topic of debate. Some studies suggest that the implementation of such a policy can lead to a reduction in green investment by firms operating in pollution-intensive sectors. On one hand, a differentiated loan interest rate restricts funding sources for these firms (Zhang et al., 2021). As polluting firms primarily engage in polluting projects, their access to loans is significantly constrained, thereby affecting them through external financing limitations (Chang et al., 2019). On the other hand, banks perceive polluting firms as facing environmental risks, resulting in increased loan costs and reduced financing (Fard et al., 2020). Consequently, these firms are compelled to decrease production and investment.

Other studies argue that the implementation of a green credit policy will promote the green investment of polluting firms. First, Green credit policies can offer financial incentives such as lower interest rates, longer repayment periods, or preferential terms for loans used specifically for green investments. These incentives make it more attractive for polluting firms to allocate funds towards environmentally friendly projects. Therefore, polluting firms have to incorporate green investment into their operations to access more bank loans after the green credit policy was adopted (He et al., 2019). Then, the polluting firms owned more credit funds are conducive

to engage in green investment behavior. Second, firms will also increase green investment to mitigate environmental risks that may lead firms to be in financial trouble under the constraints of green credit (Crona et al., 2021). Polluting firms may face increasing regulatory pressure, public scrutiny, and potential penalties for their unsustainable practices. By investing in green initiatives such as green innovation, they can mitigate these risks and improve their public image and cultivate green core competitiveness, thereby establish a good image and reputation for obtaining green credit to safeguard their long-term profitability (Chen, 2008; Saunila et al., 2018; Tang et al., 2018). The above research argues that heavy polluting firms tend to increase green investment by imposing a long-term credit constraint under the green credit policy (Ren et al., 2021; Sun et al., 2019). Therefore, the following hypothesis is proposed.

H1. Green credit policy can induce the polluting firms' green investment behavior.

Environmental information disclosure becomes an important reference for banks to understand the operation situation of firms, predict future earnings and judge expected investment risks, which will directly affect the investment activities of firms (Luo et al., 2017). The polluting firms will face stricter requirement of environmental information disclosure. Driven by green credit policies, banks will adjust their credit structure according to the information disclosed by companies (Wang et al., 2020). The disclosure of negative environmental information such as excessive pollution and carbon emissions tends to affect investors' assessment of business risk and firm value, which is not conducive to fundraising, and unbeneficial for firms to make green investments.

Although the disclosure of positive events such as environmental rewards and environmental investment can show a good image of the firm and win the favor of the capital market. When a firm performs well in environmental risk management, environmental information disclosure, and environmental performance, it will more likely to obtain external financing with a larger scale, longer duration, and lower cost (Sharfman & Fernando, 2008). However, firms with higher environmental disclosure quality may do not make more green investment, the underlying cause of this phenomenon is corporate green-washing which refers to the deceptive practice of making false or misleading claims about the environmental benefits (Xing et al., 2021). While mandatory environmental information disclosure promotes the environmental management of firms (Patten, 2002), it also increases the corresponding cost which harms the financial performance of firms and then increases the financing cost of firms (Ren et al., 2021). Therefore, the following hypothesis is proposed.

H2. The environmental information disclosure may weaken the positive effect of green credit policy on green investment.

3. Data and empirical methodology

3.1. Data sources

This paper utilizes annual data from 2010 to 2019, focusing on China's A-share listed firms as the sample. The Shenzhen Stock Exchange and Shanghai Stock Exchange have successively issued the Guide on Social Responsibility since 2006, mandating listed firms to disclose environmental information. Green investment, as a part of environmental governance, holds significant importance within the social responsibility report. However, during the experimental years of 2006 and 2007, only a limited number of listed firms disclosed social responsibility reports and related documents, resulting in a scarcity of available green governance data (Chen & Ma, 2021). Additionally, the 2008 financial crisis had a notable impact on corporate finance, necessitating its exclusion from the analysis. Consequently, the sample period spans from 2010 to 2019, representing the most recent years for data collection. After removing ST firms with unusual operations, firms with incomplete data, and those with missing values, a final dataset of 8201 observations, consisting of 1910 listed firms, is obtained. To mitigate the influence of outliers, this paper applies winsorization to all continuous variables at the 1% and 99% levels.

The data sources for this study are as follows: (1) The data on green investment are obtained from the firm social responsibility report, environmental report, and sustainable development report, which are disclosed by Cninfo Network. These reports are manually collected and organized. (2) The data regarding government subsidies are derived from the notes to the financial statements of the listed firms. (3) The ownership attribute data is sourced from the CCER Economic and Financial database. (4) The data related to financial constraints, environmental information disclosure, firm financial data, and other research variables are all obtained from the China Stock Market and Accounting Research Database (CSMAR).

3.2. Variable definition

The primary interest of this paper is a firm-level green investment, denoted by *GI*. In line with Chen and Ma (2021), firms' green investment includes expenditures and expenses related to R&D and transformation of environmental protection technology, industrial waste treatment and other pollutants treatment, purchase and construction of desulfurization and denitrification equipment and boiler reconstruction, clean and renewable projects construction, mine ecological environment restoration management and greening. We measure it in two ways: one is the natural logarithm of green investment (*GreenInvest1*), and the other is to expand the scope of green investment, include ecological product investment in the original green investment, and take the natural logarithm of total green investment (*GreenInvest2*).

According to the Guidelines for Environmental Information Disclosure of Listed firms (Draft for Soliciting Opinions) issued by China Environmental Protection Administration in 2010, and the two digit code industry classification standard of the 'Industry Classification Guidelines' (2012 Revision) published by China Securities Regulatory Commission in 2012, we define the following 15

industries as pollution intensive industries: Coal Mining and washing industry (code B06), oil and gas mining industry (code B07), ferrous metal mining and beneficiation industry (code B08), non-ferrous metal mining and beneficiation industry (code B09), textile industry (code C17), leather, fur, feather and its products and shoemaking industry (code C19), papermaking and paper products industry (code C22), petroleum processing, coking and nuclear fuel processing industry (code C25), chemical raw materials and chemical products manufacturing industry (code C26), chemical fiber manufacturing industry (code C28), rubber and plastic products industry (code C29), ferrous metal smelting and rolling processing industry (code C31), nonferrous metal smelting and rolling processing industry (code C32), metal products industry (code C33), power and heat production and supply industry (code D44). *Pollution* is a polluting industry indicator, and takes a value of one if firm *i* is in the pollution-intensive industry, zero otherwise. *Post* is an event dummy variable for the implementation of the green credit policy. It takes a value of one if after 2012, and zero otherwise.

To control for other economic characteristics and indicators that affect firms' green investment, we follow the current literature practices (Chao et al., 2021; King et al., 2021; Yao et al., 2021) and include a set of firm-level covariates that influence firms' decisions regarding green investment. These control variables include firm size (*Size*), institutional environment (*Marketindex*), firm age (*Age*), asset structure (*AS*), growth capacity (*Growth*), the proportion of independent directors (*IDR*), equity concentration (*H5*), the shareholding ratio of the largest shareholder (*Top1*). Table 1 shows the definition of key variables.

3.3. Descriptive statistics

Table 2 reports descriptive statistics for the main variables. As shown in the table, the mean value of *GreenInvest1* is 0.960, which is significantly higher than the median, indicating that the green investment of more than half of the listed firms in China is lower than the industry average, which means that listed firms have the problem of insufficient green investment. Compared with the maximum (9.158), Chinese listed firms have prominent individual heterogeneity in green investment. The mean value of *GreenInvestRatio1* is 0.004, indicating that the average proportion of green investment in firm's total assets is about 0.4%, which also shows the universality of the phenomenon of insufficient green investment. The mean value of *Pollution* is 0.594, which means that polluting firms account for 59.4% of the whole sample. Among the control variables, the descriptive statistical results of firm characteristics and corporate governance conform to the characteristics of Chinese listed firms (Chen & Ma, 2021).

3.4. Empirical methodology

Causality analysis and policy effect evaluation are fundamental issues in economic analysis. To assess policy effects, various methods such as difference-in-differences, regression discontinuity design, and randomized controlled trials (RCTs) are commonly employed to establish causal relationships between variables. However, these methods have specific application conditions and requirements. Randomized controlled trials involve randomly assigning study subjects to different interventions, allowing for the control of different effects. Regression discontinuity design, on the other hand, is a quasi-experimental method that resembles RCTs. It operates on the basic idea that there is a continuous variable *X* (referred to as the assignment variable), which determines the likelihood of an individual receiving a policy intervention on both sides of a certain critical point. As *X* is continuous around this critical point, an individual's value for *X* falling on either side of the critical point is considered random. In this paper, the primary focus is on examining the changes in green investment among different firms following the implementation of the green credit policy. The research specifically targets pollution-intensive firms and non-pollution-intensive firms, with sample grouping determined according to government classification standards. As this study does not meet the requirements for random allocation, the aforementioned methods are not applicable.

In recent years, the difference-in-differences (DID) model has gained widespread popularity for evaluating the implementation effects of public policies or projects. This model serves as a simulation of a randomized assignment experiment, allowing for the

Table 1
Variable definition.

Name	Symbol	Definition
Green investment	<i>GI</i>	GreenInvest1: ln (green investment) GreenInvest2: ln (green investment + ecological product investment)
Time dummy variable	<i>Post</i>	A dummy variable that equals 0 when all times preceding 2012, and equals 1 from 2012 onward.
Grouping dummy variable	<i>Pollution</i>	A dummy variable that equals 1 when firm <i>i</i> is in pollution-intensive industries, and 0 otherwise.
Firm size	<i>Size</i>	ln (total assets)
Debt level	<i>Leverage</i>	Liabilities/total assets
Marketization degree	<i>Marketindex</i>	The degree of marketization in the region where the firm <i>i</i> is located
Firm age	<i>Age</i>	The current year of the company minus the year of establishment
Asset structure	<i>AS</i>	Fixed assets/total assets
Growth capacity	<i>Growth</i>	(Operating revenue at the end of the current period - operating revenue at the end of the previous period)/ operating revenue at the end of the previous period
The proportion of independent directors	<i>IDR</i>	The number of independent directors/the number of board members
Equity concentration	<i>H5</i>	The sum of the square of top five major shareholders' shareholding ratio
The shareholding ratio of the largest shareholder	<i>Top1</i>	The number of shares of the first largest shareholder divided by the total number of shares

Table 2
Descriptive statistics.

Variable	N	Mean	SD	Min	Median	Max
GreenInvest1	8201	0.960	1.553	0.000	0.000	9.158
GreenInvest2	8201	1.002	1.581	0.000	0.000	9.158
GreenInvestRatio1	8194	0.004	0.019	0.000	0.000	1.181
GreenInvestRatio2	8194	0.004	0.021	0.000	0.000	1.181
Post	8201	0.832	0.374	0.000	1.000	1.000
Pollution	8201	0.594	0.491	0.000	1.000	1.000
Size	8201	8.397	1.293	5.881	8.203	12.221
Leverage	8201	0.425	0.213	0.048	0.417	0.994
MarketIndex	8201	6.240	3.237	-0.230	7.010	10.000
Age	8201	16.769	5.548	1.000	17.000	41.000
AS	8201	0.290	0.168	0.000	0.265	0.948
Growth	8201	0.184	0.564	-0.684	0.075	3.818
IDR	8190	0.370	0.053	0.182	0.333	0.667
H5	8201	0.170	0.122	0.000	0.143	0.810
Top1	8201	0.358	0.152	0.003	0.343	0.900

verification of causality in the absence of a randomized trial. By considering the implementation of a specific policy as a natural experiment, the DID model adds a control group that is unaffected by the policy to the sample, which is then compared to the experimental group consisting of sample points originally affected by the policy. This comparison aims to examine the net effect of policy implementation on the subject of analysis. When the policy is exogenous, the difference-in-differences method effectively addresses endogeneity issues (Meyer, 1995). The introduction of the green credit guidelines presents an opportunity for this paper to employ the difference-in-differences model to investigate the environmental governance effects of the green credit policy (see recent studies such as Fan et al., 2021; Wen et al., 2021).

The guidelines stipulate the relevant credit policies, systems, and management processes of banking financial institutions, and make clear requirements for the support direction and key areas of green credit, aiming to promote the transformation of economic development mode and economic structure adjustment. Therefore, this policy variable can describe the changes in the operation of the economic system and has good exogenous. Moreover, it emphasizes the implementation of the green credit concept of saving, environmental protection, and sustainable development, and do not grant credit to customers whose environmental and social performance are not in compliance. According to this principle, industries with higher pollutant emission intensity are more sensitive to the guidelines. Hence, according to the strength of the industry impacted by the policy shock, the treatment group and control group can be divided more accurately. Wen et al. (2021) study the effect of green credit policy shock on the upgrade of energy-intensive firms, following their research, taking the formal implementation of the green credit guidelines in 2012 as an event to construct a quasi-natural experiment. We build a treatment group and a control group by distinguishing whether the economic activities of micro-level firms comply with the concepts of energy conservation, environmental protection, and sustainable development, and use the DID model to investigate the impact of green credit policies on firms' green investment behavior. We set the following equation for our empirical study:

$$GreenInvest_{it} = \beta_0 + \beta_1 Post_t \times Pollution_j + \alpha X_{it} + \varphi_i + \delta_t + \varepsilon_{it} \tag{1}$$

where the dependent variable $GreenInvest_{it}$ represents the environmental investment of firm i in year t . It takes the form of either logarithm or the ratio. $Post_t$ and $Pollution_j$ are time and grouping dummy variables, respectively. When the coefficient β_1 is significantly positive, indicating that the green credit guidelines have significantly promoted the polluting firms' green investment activities. X_{it} refers to a set of control variable. φ_i and δ_t represent firm fixed effect and time fixed effect, respectively. ε_{it} is the error term. The interaction term $Post_t \times Pollution_j$ captures that the impact of the green credit policy on firms' green investment by comparing the outcome variables between firms in pollution-intensive sectors and those in non-pollution-intensive sectors, and before and post-policy periods. The coefficient of interest denoted by β_1 is the primary focus of this paper. If it is positive, the green credit policy then stimulates firms' green investments.

Fig. 2 depicts a parallel trend. The left figure compares the changes in the scale of green investment between the treatment group and the control group before and after the implementation of the Green Credit Guidelines. It can be observed that prior to the introduction of the Guidelines in 2012, the green investment of both the treatment group and the control group followed a similar trend. However, after the implementation of the Guidelines, the difference in the growth trend of green investment between the treatment group and the control group gradually expanded significantly over time. The scale of green investment in the treatment group continues to increase, while the green investment in the control group has not shown significant changes compared to the scale before 2012.

Considering the inertia and lag effect of economic factors, policy implementation often requires a process and cycle. Nonetheless, from the figure, it is evident that in the first two years following the policy implementation, the growth trend of green investment in the treatment group was slightly higher than that in the control group. Since 2015, the green investment scale of firms in the treatment group has been steadily growing. As the policy implementation period continues, its expected effect is expected to become more significant. This pattern is more clearly illustrated in the right figure, which plots the estimates of the policy effect parameter. It can be observed that the parameter shows weak significance before 2012, but became significant and gradually increased after 2012. These

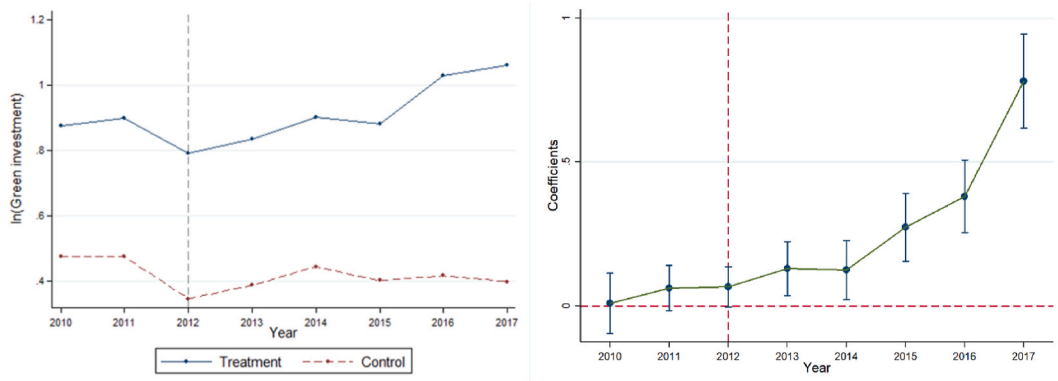


Fig. 2. Parallel trend of green credit policy on firms' green investment. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

results support the parallel trend hypothesis and provide preliminary evidence for our assumption that green credit guidelines drive pollution-intensive firms to increase their green investment.

4. Empirical results

4.1. Baseline results

The DID model is employed to estimate the impact of the green credit policy on firms' green investment behavior. Table 3 presents the regression results of the green credit policy on firms' green investment. In Columns (1) and (3), we control for firm fixed effects and year fixed effects, without considering the influence of firm characteristics and corporate governance on firms' green investment decisions. In Columns (2) and (4), we introduce a set of control variables. The results indicate that the coefficient of $Post \times Pollution$ is significantly positive, indicating that, compared with non-polluting firms, the green credit policy can significantly promote the green investment of firms in the pollution-intensive sectors, supporting Hypothesis 1. Our preferred baseline results are based on Columns (2) and (4), where we include control variables. The economically significant findings suggest that after the implementation of green credit policies, the average green investment of heavily polluting firms increases by 27.40% or 25.35%.¹

The objective of green credit is to provide support for investment projects focused on environmental improvement and climate change while restricting investments in polluting projects. Non-polluting industries mainly comprise clean and environmentally friendly sectors or service industries that have low pollution and energy consumption. Consequently, their investment and financing activities face fewer limitations imposed by the green credit policy. The introduction of green credit guidelines aims to restrict bank loans for polluting projects and encourage the transformation of heavily polluting industries towards more environmentally friendly practices, necessitating increased green investment. China has recognized the significant pressure on resources and the environment resulting from the extensive development model of its traditional manufacturing industry, characterized by high pollution and energy consumption. As a result, China has placed greater emphasis on ecological and environmental issues. The 19th National Congress of the Communist Party of China has called for the implementation of the strictest ecological and environmental protection measures to ensure the construction of an ecological civilization. With the tightening of environmental regulations, heavily polluting firms are facing stricter environmental supervision. Supporting green transformation through environmental protection practices and reducing the environmental costs associated with pollution have become urgent priorities. Thus, increasing green investment is a prudent choice for polluting firms. The green credit policy serves as a catalyst for encouraging green investment by these firms, enabling them to overcome the limitations imposed by green credit restrictions, secure bank loans, and expand their green investment endeavors.

4.2. Parallel trends test

The establishment of the DID method relies on an important assumption: the treatment group and the control group should not be affected by the treatment effect, and their dependent variables should exhibit a parallel trend. In this study, we test the dynamic performance of firms' green investment in the two years prior to implementation and five years following the implementation of the green credit policy, based on the selected time window. The results from the test, as presented in Table 4, demonstrate no significant difference in green investment between the treatment group and the control group before the implementation of the green credit policy. However, after the introduction of the Guidelines, there is a significant increase in the scale of green investment. These findings support the parallel trend hypothesis of the DID method employed in this paper. Consequently, it can be concluded that the green

¹ In Column (2) of Table 3, the coefficient of $Post \times Pollution$ is 0.263/the mean value (0.960) of $GreenInvest1 = 0.2740$, that is, 27.40%; In Column (4) of Table 3, the coefficient of $Post \times Pollution$ is 0.254/the mean value (1.002) of $GreenInvest2 = 0.2535$, that is, 25.35%.

Table 3
The impact of green credit policy on green investment.

Variable	GreenInvest1		GreenInvest2	
	(1)	(2)	(3)	(4)
Post × Pollution	0.242*** (3.08)	0.263*** (3.36)	0.226*** (2.81)	0.254*** (3.16)
Firm Controls	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	6361	6350	6361	6350
R-squared	0.016	0.024	0.012	0.020

Notes: Dependent variables include the logarithm of green investments and the ratio of green investments. T-statistic values are presented in the parenthesis. All columns include a set of fixed effects at the firm and year levels. Firm control variables include a set of potential factors affecting firms' green investment decisions. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table 4
Parallel trends analysis.

Variable	GreenInvest1		GreenInvest2	
	(1)	(2)	(3)	(4)
Post ₂₀₁₀ × Pollution	0.013 (0.24)	-0.007 (-0.08)	-0.003 (-0.06)	-0.012 (-0.14)
Post ₂₀₁₁ × Pollution	0.061 (1.53)	0.033 (0.63)	0.047 (1.19)	0.024 (0.46)
Post ₂₀₁₃ × Pollution	0.064* (1.81)	0.054 (1.24)	0.078** (2.14)	0.064 (1.44)
Post ₂₀₁₄ × Pollution	0.134*** (2.82)	0.140* (1.86)	0.156*** (3.07)	0.152* (1.95)
Post ₂₀₁₅ × Pollution	0.134** (2.54)	0.120 (1.26)	0.142** (2.55)	0.111 (1.12)
Post ₂₀₁₆ × Pollution	0.283*** (4.66)	0.255** (2.22)	0.266*** (4.17)	0.211* (1.74)
Post ₂₀₁₇ × Pollution	0.369*** (5.64)	0.317** (2.39)	0.301*** (4.42)	0.216 (1.55)
Firm Controls	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	6361	6350	6361	6350
R-squared	0.014	0.022	0.010	0.018

Notes: Dependent variables include the logarithm of green investments and the ratio of green investments. T-statistic values are presented in the parenthesis. All columns include a set of fixed effects at the firm and year levels. Firm control variables include a set of potential factors affecting firms' green investment decisions. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table 5
Robustness tests.

Variable	Alternative Dependent Variables		Alternative Control Variables		Redefine Polluting Industries	
	GreenInvestRatio1	GreenInvestRatio2	GreenInvest1	GreenInvest2	GreenInvest1	GreenInvest2
	(1)	(2)	(3)	(4)	(5)	(6)
Post × Pollution	0.349** (2.12)	0.367** (2.15)	0.261*** (3.36)	0.251*** (3.16)	0.204*** (2.75)	0.193** (2.54)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6349	6349	6306	6306	6591	6591
R-squared	0.010	0.008	0.023	0.019	0.031	0.027

Notes: Dependent variables include the logarithm of green investments and the ratio of green investments. T-statistic values are presented in the parenthesis. All columns include a set of fixed effects at the firm and year levels. Firm control variables include a set of potential factors affecting firms' green investment decisions. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

credit policy exerts a considerable influence on the green investment behavior of pollution-intensive firms.

4.3. Robustness test

This paper conducts three types of robustness tests. Firstly, green investment is adjusted by deflating it with firms’ operating revenue at the end of the year, expressed as the ratio of green investment (GreenInvestRatio1) and the sum of green investment and ecological product investment (GreenInvestRatio2) to operating revenue, respectively. Secondly, adjustments are made to the control variables. The measurement of firm growth capacity is changed from the growth rate of operating revenue (Growth) to the growth rate of total assets (Growth2). Additionally, the proxy indicators of corporate governance are modified from IDR, Top1, and H5 to Separation (the separation rate of control and ownership of listed firms owned by actual controllers), Dual (indicating whether the chairman and general manager positions are held by the same person), Supervisor (the size of the supervisory board, represented by the logarithm of the number of supervisors), and Four commission (the number of established committees: audit, strategy, nomination, and salary/assessment). Thirdly, the pollution industry of the treatment group is redefined. Instead of following the standards of the Guidelines for Environmental Information Disclosure of Listed Firms, the heavily polluting industries are now redefined based on the Classified Management Directory of Environmental Protection Verification Industries of Listed Firms issued by the China Environmental Protection Administration in 2008, with reference to the Industry Classification Guidelines’ (2012 Revision). Regression analysis of Equation (1) is then repeated, and the results are presented in Table 5. The test results indicate that the baseline results remain largely unchanged when adjusting the measurement of the dependent variable, modifying control variables, and redefining the pollution industry. This suggests that the green credit policy effectively stimulates green investment in polluting firms.

4.4. Endogenous issues

Through the use of policy documents issued by Chinese government agencies as the defining standard for identifying polluting firms, this paper establishes a treatment group and a control group to examine the impact of green credit policy on firms’ green investment. However, the obtained results may be affected by sample selection bias. To address this issue and mitigate potential systematic differences between the changing trends of treatment group firms and control group firms, the PSM-DID method is employed for further analysis, following the approach outlined in Yao et al. (2021). The propensity score is derived through a Logit regression of the control variable, considering whether a firm is a virtual variable for a polluting firm. We utilize the k-nearest neighbor matching principle ($k = 1$) to pair the samples. Specifically, the firms with the closest propensity score are matched as paired firms for the polluting firms. This approach aims to minimize systematic differences in the scale of green investment across different firms. The results presented in Columns (1) and (2) of Table 6 demonstrate that the implementation of the green credit policy still significantly promotes green investment among polluting firms.

However, starting around 2012, the Chinese government also implemented several other measures related to environmental protection, introducing significant environmental policies and regulations. These factors might contribute to differences in green investment between polluting and non-polluting firms, which can confound the impact of the green credit policy on the green investment of polluting firms. As a result, the estimates might capture the effects of other confounding policies. To demonstrate that the promotion of green investment is specifically influenced by the green credit policy and not other factors, this study incorporates the following placebo tests. In October 2011, the Chinese government launched a pilot with Carbon Emission Trading System (ETS) in seven provinces or cities, namely Beijing, Shanghai, Tianjin, Chongqing, Hubei, Guangdong, and Shenzhen. To account for the potential influence of this policy on firms involved in low-carbon activities, we excluded the sample of firms located in these provinces and cities where the ETS Pilot projects were implemented. The research samples from the seven provinces and cities mentioned above were excluded from the overall sample. The results in columns (3)–(4) of Table 6 indicate that the coefficient of the interaction term $Post \times Pollution$ remains significantly positive. This finding suggests that the expansion of green investment among polluting firms after the implementation of the green credit guidelines is indeed associated with the introduction of the green credit policy, while other

Table 6
Endogenous check (1).

Variable	PSM-DID		Exclude ETS samples	
	GreenInvest1	GreenInvest2	GreenInvest1	GreenInvest2
	(1)	(2)	(3)	(4)
Post × Pollution	0.261*** (3.33)	0.252*** (3.15)	0.276*** (3.14)	0.271*** (2.98)
Firm Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	6299	6297	4744	4744
R-squared	0.024	0.019	0.023	0.021

Notes: Dependent variables include the logarithm of green investments and the ratio of green investments. T-statistic values are presented in the parenthesis. All columns include a set of fixed effects at the firm and year levels. Firm control variables include a set of potential factors affecting firms’ green investment decisions. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

factors are not contributing factors.

On January 1st, 2015, the Chinese government officially implemented the Environmental Protection Law, aimed at protecting and improving the environment and promoting sustainable economic and social development. It is considered the strictest environmental protection law in Chinese history. In September of the same year, the State Council issued the Overall Plan for the Reform of Ecological Civilization System, which emphasizes the importance of resource conservation and environmental protection as a fundamental national policy. To eliminate the potential influence of the aforementioned legislation, we shortened the research period to 2014 (covering the years 2010–2014) to ensure that the observed effects on polluting firms' green investment behavior were solely attributable to the green credit policy. The results in Columns (1)–(2) of Table 7 indicate that the coefficient of $Post \times Pollution$ remains significantly positive, suggesting that the expansion of green investment by polluting firms is not a result of the Environmental Protection Law and the Overall Plan. Thus, it confirms the promotional effect of the green credit policy on green investment.

In September 2013, the Chinese State Council issued the Air Pollution Prevention and Control Action Plan (referred to as "Air Ten"), which outlined measures for preventing and controlling air pollution in various sectors, including coal combustion, industry, motor vehicles, and early warning systems for heavy pollution. This plan provided a comprehensive roadmap for air pollution control until 2017 and set specific targets for reducing PM2.5 concentration in provinces and cities. It also introduced strict penalties for environmental violations, influencing firms' environmental behavior. To distinguish the increase in green investment from the response of polluting firms to comply with Air Ten, we further narrowed down the sample period to the year prior to the plan's promulgation in 2013. The results in Columns (3)–(4) of Table 7 indicate that the coefficient of $Post \times Pollution$ remains significantly positive, suggesting that the green credit policy continues to have a significant impact on promoting green investment by polluting firms, even when considering the exclusion of the influence of Air Ten.

Additionally, in 2012, the report of the 18th CPC National Congress emphasized the significance of placing ecological civilization at the forefront. Furthermore, on December 15, 2011, the State Council issued the "12th Five-Year Plan" for Environmental Protection, which aimed to reduce pollutant emissions from high-energy consumption and heavily polluting industries, promote cleaner production, and develop a circular economy to foster the construction of ecological civilization. To mitigate the potential influence of these environmental policies on the development of the green economy, we adjusted the timing of policy events and designated 2011 as the dividing point. The sample period includes two years before and after 2011 (2009–2012). We introduced an event dummy variable, $Post2011$, which takes the value of 0 for the years prior to 2011 and 1 for 2011 onwards. If the conclusion of this paper reflects the impact of the green credit policy rather than the effects of the 18th CPC National Congress and the "12th Five-Year Plan" for Environmental Protection, then the coefficient of the interaction term $Post2011 \times Pollution$ should not be statistically significant. Based on the results presented in Columns (5)–(6) of Table 7, the coefficient of $Post2011 \times Pollution$ is positive but not statistically significant. This indicates that the baseline conclusion is not influenced by other environmental policies and regulations, supporting the argument that the observed effects are primarily driven by the green credit policy.

5. Further discussion

5.1. Policy expansion analysis

To further enhance China's green financial system and strengthen the role of green finance in supporting high-quality development and environmental transformation, the China Banking Regulatory Commission (CBRC, 2012) issued the green credit guidelines in 2012. Subsequently, in 2018, the People's Bank of China introduced two policies: the Notice on Carrying out the Evaluation of Green Credit Performance of Banking Deposit Financial Institutions and the Notice on Establishing a Special Statistical System for Green

Table 7
Endogenous check (2).

Variable	Exclude interference from other environmental policies and regulations					
	Environmental protection law		Air Ten		"12th Five-Year Plan" for Environmental Protection	
	Sample for 2010–2014		Sample for 2010–2012		Sample for 2009–2012	
	GreenInvest1	GreenInvest2	GreenInvest1	GreenInvest2	GreenInvest1	GreenInvest2
	(1)	(2)	(3)	(4)	(5)	(6)
$Post \times Pollution$	0.146*	0.138*	0.159**	0.156**		
	(1.96)	(1.85)	(2.07)	(2.05)		
$Post^{2011} \times Pollution$					0.098	0.123
					(1.12)	(1.40)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3724	3724	2142	2142	2690	2690
R-squared	0.014	0.015	0.014	0.012	0.010	0.009

Notes: Dependent variables include the logarithm of green investments and the ratio of green investments. T-statistic values are presented in the parenthesis. All columns include a set of fixed effects at the firm and year levels. Firm control variables include a set of potential factors affecting firms' green investment decisions. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Loans. These policies served as supplements and extensions to the green credit guidelines. The question arises: Did these two documents, introduced in 2018, further amplify and reinforce the impact of the green credit policy on green investment? As mentioned earlier, we take the implementation of these two policies in 2018 as a new time reference point to examine the changes in policy impact during the two years before and after 2018. In this analysis, we introduce the event dummy variable *Post2018*, which signifies the implementation of the supplementary regulations related to the green credit guidelines. Specifically, for the years before 2018, the value of *Post2018* is 0, whereas it is 1 for 2018 onwards. The interaction term *Post2018*×*Pollution* reflects the sustained effect of the policy. The results of this analysis are presented in columns (1)–(2) of Table 8. Compared to the results in Table 3, the coefficient of the interaction term *Post*×*Pollution* demonstrates a higher level of statistical significance in columns (1)–(2). This indicates that the further implementation of the green credit policy has effectively enhanced the green investment activities of polluting firms and compelled them to transition towards environmentally friendly practices. In columns (3)–(4), the results demonstrate that the green credit guidelines can stimulate firms to engage in green investments over a more extended period of time. Building upon these findings, we investigated the linkage between the policy events in 2012 and 2018 to examine whether the green credit policy had a consistent positive impact on firms’ environmental practices. The results in columns (5)–(6) indicate that the green credit policy has continuously and significantly promoted the green investment behavior of firms in pollution-intensive sectors. Furthermore, it is noteworthy that the inclusion of the green credit policy in bank assessments in 2018 made its implementation mandatory, resulting in a stronger implementation effect.

5.2. Heterogeneous effects

Our sample encompasses firms with diverse characteristics and types, exhibiting significant variations in their investment levels. Considering the substantial individual differences exhibited by these firms, it becomes crucial to investigate the heterogeneous effects of green credit policies on their green investment.

5.2.1. Differences in environmental information disclosure

Table 9 shows that the promotion effect of green credit on green investment is more significant in firms that don’t disclose environmental information, indicating that some firms have the phenomenon of “green wash” (Walley & Whitehead, 1994). Hypothesis 2 is tenable with the empirical results. China Securities Regulatory Commission has not put forward mandatory requirements for listed firms to disclose environmental information. Although the disclosure of environmental information can release the pro-social attitude of firms to the outside world, while a firm’s environmental performance is terrible, the disclosure of environmental information will damage the firm’s image and reputation, so concealing information can reduce the corresponding external pressure. Under strict environmental regulation and fierce market competition, some firms are unwilling to bear the cost burden and revenue uncertainty caused by green investment, as well as the possible loss of vested profit. Therefore, it is possible to “green-washing” firm image, which means that the improvement effect of green investment on environmental performance will not be significant. Consequently, the promotion effect of green credit on green investment is more significant in firms that give up disclosing environmental information.

5.2.2. Differences in financial support

In this section, we conduct further tests to examine the moderating roles of financial constraints and government subsidies. We employ the SA index as a measure of firms’ financing constraints. This choice is supported by previous studies confirming the impact of firm size and age on financing constraints (Hadlock & Pierce, 2010), along with the exogenous nature of these two variables. The SA index is calculated as follows: $SA = 0.737 * Size + 0.043 * Size^2 - 0.04 * Age$, where Size represents firm size and Age represents firm age. A higher SA index indicates lower financing constraints faced by firms. We divide the research samples into two groups based on the mean value of the SA index: high degree of financing constraint (High-FC, SA index < mean value) and low degree of financing constraint (Low-FC, SA index > mean value). Government subsidies received by firms are used to measure the level of government

Table 8
Results of policy expansion analysis.

Variable	Sample for 2016–2019		Sample for 2010–2019			
	GreenInvest1	GreenInvest2	GreenInvest1	GreenInvest2	GreenInvest1	GreenInvest2
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Post</i> ²⁰¹⁸ × <i>Pollution</i>	0.448*** (2.72)	0.448*** (2.71)			0.293** (2.04)	0.288** (1.99)
<i>Post</i> × <i>Pollution</i>			0.241*** (3.09)	0.229*** (2.85)	0.277*** (3.55)	0.265*** (3.30)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3655	3655	8190	8190	8190	8190
R-squared	0.192	0.180	0.120	0.104	0.122	0.106

Notes: Dependent variables include the logarithm of green investments and the ratio of green investments. T-statistic values are presented in the parenthesis. All columns include a set of fixed effects at the firm and year levels. Firm control variables include a set of potential factors affecting firms’ green investment decisions. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table 9
Heterogeneity analysis of environmental information disclosure.

Variable	GreenInvest1		GreenInvest2	
	Disclose	No Disclose	Disclose	No Disclose
	(1)	(2)	(3)	(4)
Post × Pollution	0.233 (1.47)	0.226*** (2.60)	0.196 (1.26)	0.232** (2.55)
Firm Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Observations	1421	4929	1421	4929
R-squared	0.042	0.023	0.037	0.020

Notes: Dependent variables include the logarithm of green investments and the ratio of green investments. T-statistic values are presented in the parenthesis. All columns include a set of fixed effects at the firm and year levels. Firm control variables include a set of potential factors affecting firms' green investment decisions. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

support. We measure it as the natural logarithm of the average subsidies received at the beginning and end of the year. Similarly, we divide the research samples into two groups based on the mean value of government subsidies: more subsidies (Large subsidy, government subsidies > mean value) and fewer subsidies (Small subsidy, government subsidies < mean value).

Based on the results presented in Table 10, we observe that the promotion effect of the green credit policy on the green investment of polluting firms is more pronounced in firms with lower financing constraints. This finding suggests that lower financing constraints contribute to the transformation of polluting firms towards green practices. Firms with lower financing constraints possess greater capital allocation capabilities. On one hand, these firms are motivated to engage in green investments in order to maintain a favorable green image and secure more loans from banks. On the other hand, firms with lower financing constraints voluntarily increase their green investment to expedite the process of transformation and upgrading, thereby reducing the risks associated with environmental compliance. Such firms face less resistance in obtaining credit and other funds due to their robust environmental risk management, which subsequently lowers their cost of debt financing (Sharfman & Fernando, 2008). Moreover, investment in green technological innovation enhances firms' environmental performance and can lead to competitiveness subsidies (Xu et al., 2021). Consequently, firms that are not constrained by financing increase their investment in green practices. These findings align with the conclusions drawn by Yao et al. (2021) that the green credit policy enhances green investment, particularly among firms with lower financing constraints.

Furthermore, the role of the green credit policy in promoting the green investment of polluting firms is particularly significant in firms with fewer government subsidies. This finding suggests that government subsidies can "crowd out" the resources and motivation of firms to engage in green investment (Shleifer & Vishny, 1994). The presence of government subsidies can diminish firms' incentives and willingness to participate in green innovation and investment Li et al., 2022. Moreover, when higher subsidies are provided, firms may focus on implementing more expensive yet cleaner green technologies (Yang et al., 2019). However, it should be noted that the government's subsidy policy alone cannot guarantee substantial investments in green innovation or a significant reduction in overall carbon emissions, as the extent of green investment is also influenced by the associated costs (Li et al., 2021). As a result, after receiving government subsidies, firms may reduce their green investment efforts, leading to a phenomenon of "substitution" between government subsidies and green investment in terms of resource allocation.

5.2.3. Differences in firm characteristics

In our sample, which includes all A-share listed firms, significant individual differences exist among them. It is intriguing to explore

Table 10
Heterogeneity analysis in financial support.

Variable	Financial Constraints				Government Subsidy			
	GreenInvest1		GreenInvest2		GreenInvest1		GreenInvest2	
	High-FC	Low-FC	High-FC	Low-FC	Large Subsidy	Small Subsidy	Large Subsidy	Small Subsidy
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × Pollution	0.130 (1.58)	0.271* (1.77)	0.124 (1.48)	0.286* (1.87)	0.023 (0.13)	0.296*** (3.11)	0.023 (0.13)	0.266*** (2.69)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3696	2654	3696	2654	1297	5053	1297	5053
R-squared	0.018	0.033	0.017	0.030	0.030	0.026	0.031	0.020

Notes: Dependent variables include the logarithm of green investments and the ratio of green investments. T-statistic values are presented in the parenthesis. All columns include a set of fixed effects at the firm and year levels. Firm control variables include a set of potential factors affecting firms' green investment decisions. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

whether and how the aforementioned conclusions may vary due to heterogeneity in characteristics. Thus, this section delves into the heterogeneity effect to examine the impact of green credit policy on a firm's green investment in terms of ownership type, firm size, and environmental information disclosure.

As depicted in Columns (1)–(4) of [Table 11](#), the impact of green credit policy on promoting green investment among polluting firms is significantly positive for State-Owned Enterprises (SOEs) compared to non-SOEs. SOEs benefit from government guarantees and favorable financing arrangements, resulting in fewer financing constraints ([Li & Liu, 2009](#)). On the other hand, non-SOEs often encounter credit discrimination, which limits their access to funds. SOEs have ample resources for investment allocation, while non-SOEs, being relatively smaller in scale, face higher financing risks when engaging in green investment. Additionally, SOEs often undertake tasks aligned with national policies and prioritize their corporate image, making green investment more advantageous. Consequently, green credit has a stronger incentivizing effect on the green investment behaviors of SOEs.

Due to the significant differences in function and attributes between SOEs and non-SOEs, non-SOEs experience more challenges and difficulties during policy reforms ([Fan et al., 2021](#)). In columns (5)–(8), we further divide the sample into large-size firms (Large-size, Size > median value) and small-size firms (Small-size, Size < median value) using the median as the threshold. The results indicate that the incentive effect of green credit policy on green investment is more pronounced in large-size polluting firms compared to small-size firms. This suggests that small-size firms face a greater burden of costs when undertaking green transformation efforts.

6. Conclusions and implications

6.1. Conclusions

While numerous studies have examined the various impacts of the Chinese green credit policy, there is a notable absence of research on its specific impact on green investment. This study aims to fill this gap by exploring how the green credit policy effectively allocates credit resources and stimulates the green transformation of Chinese firms. We consider the promulgation of green credit guidelines in 2012 as a quasi-natural experiment and employ the Difference-in-Differences (DID) model to examine the effects of the green credit policy on the green investment behavior of polluting firms. The main findings are as follows: Compared to non-polluting firms, the green credit policy significantly promotes the green investment of polluting firms. This incentive effect remains sustainable throughout the implementation cycle. The implementation of supplementary regulations of the green credit policy in 2018 further strengthens the green investment activities of polluting firms and encourages their transformation towards environmentally friendly practices. The analysis of the heterogeneity effect reveals that the green credit policy facilitates the green investments of firms with undisclosed environmental information. Additionally, we found that polluting firms with soft financial constraints, limited access to government subsidies, state-owned firms, and larger size demonstrate more pronounced advantages in promoting green investment through the green credit policy.

6.2. Implications

Possible policy implications from our empirical findings are four-fold. First, the government should increase the delivery of green credit in quantity and scope, and stimulate social capital to participate in green practices. Specifically, China faces three key tasks in enhancing its green credit policies and service systems: (1) Establishing and improving the performance evaluation mechanism for green investment and financing, and enhancing supervision, rewards, and penalties for financial institutions and supportive companies to stimulate social capital investment in green industries. (2) Actively innovating green financial products and diversifying financing modes and subjects. This entails optimizing project credit cycles, costs, and amounts, as well as conducting comprehensive assessments of creditworthy firms. (3) Ensuring the sustainability and resilience of credit policies to facilitate a smooth transition of companies towards green practices.

Second, it is recommended to expand the coverage and enhance the transparency of environmental information disclosure to mitigate environmental risks linked to credit projects. The validation of Hypothesis 2 highlights the importance of mandatory environmental information disclosure by heavily polluting firms to facilitate authentic green transformation and deter greenwashing practices. It is advisable to incorporate criteria such as the firm's green image, scale of green investment, and level of environmental information disclosure into the green credit evaluation process conducted by banking and financial institutions. This will strengthen the assessment of firms' environmental performance and enhance the effectiveness of green credit policies.

Third, government subsidies serve as a supplemental rather than an essential factor in promoting green transformation. A moderate amount of subsidies can help alleviate the challenges arising from financing constraints. It is important to enhance the incentive effect of government subsidies, prevent the crowding out of green investment, and promote synergy between government subsidies and green credit financing.

Furthermore, in implementing the green credit policy, it is crucial to avoid a one-size-fits-all approach for polluting firms and instead provide differentiated loans based on the specific nature of their projects to facilitate their transformation. Particularly, the government should pay attention to the credit and financial difficulties faced by small and medium-sized firms, as well as private firms, in their green transformation journey.

6.3. Limitations and future research opportunities

However, our study does have certain limitations. When examining the shock effects of a specific policy, it is important to consider

Table 11
Heterogeneity analysis along ownership type and firm size.

Variable	Ownership Type				Firm Size			
	GreenInvest1		GreenInvest2		GreenInvest1		GreenInvest2	
	SOEs	non-SOEs	SOEs	non-SOEs	Large	Small	Large	Small
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × Pollution	0.362*** (2.69)	0.106 (1.28)	0.363*** (2.69)	0.076 (0.87)	0.323** (2.01)	0.124 (1.61)	0.349** (2.18)	0.128 (1.62)
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2695	3592	2695	3592	2948	3402	2948	3402
R-squared	0.043	0.019	0.039	0.012	0.036	0.015	0.034	0.012

Notes: Dependent variables include the logarithm of green investments and the ratio of green investments. T-statistic values are presented in the parenthesis. All columns include a set of fixed effects at the firm and year levels. Firm control variables include a set of potential factors affecting firms' green investment decisions. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

other policies that may have been introduced during the same period. For instance, the policy shock triggered by the promulgation of the Chinese Environmental Protection Law in 2015 could have had mixed effects on our baseline results. While we have conducted robustness tests to mitigate these potential interferences and identify the economic consequences of the target policy, we were unable to fully address the issue of policy combination effects. The existing literature also lacks clear solutions to this problem. Therefore, an important direction for future research is to identify which groups are affected by specific policies before applying the Difference-in-Differences (DID) method.

Additionally, our study primarily focuses on the external effects of policy factors on firm green investment behavior, without extensively exploring the influence of internal factors, particularly corporate governance factors. There is a need for further research in this area to gain a more comprehensive understanding of the relationship between internal factors and firm green behavior. Investigating this relationship would contribute to the micro-level evidence of the operational mechanisms driving green investment. In conclusion, while our study sheds light on the impact of policy factors on firm green investment behavior, there are still avenues for future research to address limitations related to policy interference and the exploration of internal factors and corporate governance.

Declaration of interest statement

All authors provide critical feedback and help shape the research, analysis and manuscript. They contribute equally to this study and share first authorship. The authors have no conflicts of interest to declare.

Data availability

Data will be made available on request.

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