Research article

The impact of green credit legislation on business financing: Insights from Chinese polluting firms

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A B S T R A C T

Introducing sustainable credit protection by companies depends on eco-friendly funding that accelerate businesses' technical development and transformation. This study investigates the sustainable financing roles through green credit legislation which impacted state owned enterprises and non state owned enterprises. We have investigated our hypothesis using the Propensity Score Matching Difference-in-Differences (PSM-DID) model. For this purpose we collected data of businesses listed on the Shanghai and Shenzhen stock exchanges that are country's most polluting publicly listed enterprises between 2009 and 2021. The results of the study reveals that liquid Finance and industrial Credit experienced a meteoric rise while the use of illiquid debt financing has dropped significantly among highly polluting organizations. This pattern has intensified after China introduced its "sustainable credit guidelines." Additionally, businesses in areas with lower sustainable development indices are more likely to feel the consequences of sustainable credit programs. However, there is still a need for prudent capital flow allocation in response to the personalized financing preferences resulting from the sustainable credit policy at the business level, even if China's sustainable credit rules have unquestionably reduced the use of illiquid debt financing by severely polluting enterprises. Policy implications include improving the direction signalled to these businesses via sustainable funding.

1. Introduction

The contemporary construction sector has been transitioning towards prefabricated structures in order to further sustainable development, a pattern driven by the growing emphasis on Environmental, Social, and Governance (ESG) concerns worldwide. Although ESG features play a crucial role in attaining sustainability objectives, more research needs to be done that particularly focuses on these attributes in relation to prefabricated buildings. ESG policies differ significantly between industrialized and developing countries, with the former being more susceptible to rigorous ESG rules. The exponential growth of building construction, which has been consistently reaching close to 4 billion square meters per year since 2013, indicates a notable and important pattern in the construction sector. Projections suggest that there will be a significant increase in expansion in the next few decades, with a projected addition of 33 billion square meters by 2040 and an additional 17 billion square meters by 2060. The upward trend in expansion highlights the growing need for creative and environmentally friendly construction solutions to address the changing requirements of urbanization and infrastructure development. The use of prefabricated buildings, which includes manufacturing standardized building

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components in a factory and assembling them on-site, presents a significant opportunity for sustainable change in the construction industry. The implementation of prefabricated construction techniques is being expedited 'due to policy directives, digital advancements, and the incorporation of Building Information Modelling (BIM) technology. This demonstrates a deliberate reaction to the difficulties presented by conventional building design and construction methods [1]. Europe has a strong policy drive to prioritize Nature-based solutions (NBS)[1] over conventionally designed infrastructure. As a result, cities are developing infrastructure rules that give first billing to natural systems and resources. According to the European Commission, Nature-based solutions (NBS) are "solutions that are influenced and supported by nature, which are cost-effective, provide environmental, social, and economic benefits, and contribute to building resilience" (European Commission, 2015). Extensive natural reserves, forestry projects, meso-level riparian buffers, concrete parks, and even local sustainable walls and roofs are all included in NBS [2]. While Nature-based solutions (NBS) is said to be more environmentally friendly and cost-effective than conventional gravy infrastructure, it has yet to catch on [3]. The lack of standardized design criteria, political resistance, sectoral approaches to Nature-based solutions (NBS), dependence on existing pathways, technological uncertainty, funding shortages, institutional capacity gaps, and the absence of a legal framework for Nature-based solutions (NBS) implementation are just some of the obstacles previously identified by researchers [4]. Recent academic interest has focused on one of these difficulties: the possibility of making a profit through NBS. Although Nature-based solutions (NBS) projects help society greatly, they need more income to pay the high start-up expenses [5]. Nature-based solutions (NBS) initiatives often depend on public Finance because of their low-income potential and susceptibility to market failures like free-riding. Budgets for non-essential initiatives, such as Nature-based solutions (NBS), have traditionally been cut by governments as part of ongoing austerity programs [6]. Traditional accounting methods fail to capture the economic worth of natural assets, contributing to this lack of investment [7].

Researchers have started looking into Nature-based solutions (NBS) from a business model viewpoint to strengthen its financial case. They aim to show how Nature-based solutions (NBS) provides value and find economic models to convert it into actual cash streams [8]. Mechanisms to mobilize private funding for NBS from institutional investors, businesses, and people are receiving more and more focus as time goes on [9]. Several alternative options, including tax increment financing, land value capture, impact bonds, and crowdfunding, are discussed in recent assessment of NBS financing difficulties and solutions [10]. Alternative Finance (AF) refers to a broad category of funding strategies not supported by the general taxes of the populace. Recent years have seen explosive development in alternative Finance, which includes equity-based and reward-based crowdfunding, peer-to-peer financing, and peer-to-business Finance [11]. [12] estimate that the alternative finance sector was worth $89 billion in 2018, up from $61 billion in 2017 (excluding China). With $215.37 billion earned in 2018, China was the global leader in alternative fintech. The United States followed this with $61 billion and the United Kingdom with $10.4 billion. Marketplace lending accounted for 64 % of total funds raised in 2018 [13], even though the global alternative finance market increased in volume by a significant margin. Given the current political, legal, and economic instability, together with new developments in areas such as financial technology, climate change, clean technology, and sustainable Finance, it is crucial to have a firm grasp of the factors propelling alternative Finance's growth.

However, most of the available research needs to be revised, such as a concentration on specific debt measures and a lack of attention to alternative financing, which make it difficult to draw firm conclusions about the influence of sustainable credit policies on business funding restrictions [14]. Although some studies combine long- and short-term loans into one category called "bank loans," researchers often focus on each kind of borrowing in isolation. Lack of impartiality in assessing the efficacy of sustainable credit programs may result from ignoring firms' choices on alternative funding [15]. There seems to be a dynamic between corporate credit ratings and bank loans, with businesses turning to industrial Credit as a backup funding source [16]. While there is some evidence that sustainable credit policies have helped reduce energy waste, emissions, and pollution and even protected the environment, the prevalence of other financing options suggests that these policies have not effectively managed the flow of money [17]. Therefore, the policy's signalling guidance has to be tightened up.

The background of green credit legislation states a 'Equitor Principles[2]' proposed by International Finance Corporation in 2002, recognized by 39 countries. This was one of World Economic Forum collaboration with 'Declaration of collaborators on Financial

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[1] Nature-based solutions (NBS) are novel strategies that utilize natural processes and ecosystems to tackle environmental, social, and economic difficulties. The European Commission states that Natural-Based Solutions (NBS) are economically efficient methods that are backed by nature. These solutions offer several advantages, such as promoting biodiversity, strengthening resilience, and reducing the impacts of climate change. Some examples of nature-based solutions (NBS) include the restoration of forests, wetlands, and urban green areas, as well as the implementation of sustainable agriculture methods. The objective of these solutions is to incorporate natural features into urban and rural development in order to establish communities that are more sustainable and resilient. Obstacles, including the absence of standardized design requirements, political opposition, and insufficient finance, impede the extensive implementation of NBS.

[2] The Equator Principles, introduced by the International Finance Corporation (IFC) in 2002, serve as a risk management framework that financial institutions use to identify, evaluate, and control environmental and social risks associated with projects. These principles, acknowledged in 39 countries, strive to guarantee that projects are executed in a socially responsible manner and adhere to effective environmental management methods. By adopting the Equator Principles, a financial institution demonstrates its dedication to both environmental sustainability and social responsibility. More than 111 financial institutions worldwide have adopted these principles, leading to over 70 % of credit operations in the US and UK being carried out under this framework. The principles advocate for the advancement of eco-friendly credit innovation, mitigation of eco-friendly credit risks, and enhancement of eco-friendly credit management. This leads to a substantial transformation in the approach of financial institutions towards project financing, especially in industries that cause pollution. Financial institutions can mitigate environmental and social risks and promote global environmental sustainability initiatives by following these principles. This will ensure that projects align with sustainable development goals.

Institutions and Sustainable Development'. More than 111 financial institutions adopted this green legislation effectively. Meanwhile the international green credit market acknowledged and promoted green credit innovation, reduces green credit risk and strengthen the green credit management. Once the 'equator principles' become successfully operational more than more 70 % of US and UK credit operations were performed under this platform.

The effects of industrial Credit on a company's financing structure are analyzed, and the notion that industrial Credit might serve as a viable alternative financing option is tested.

There are three main contributions to this study. First, it shows that alternative financing concepts like market-driven industrial Credit may supplement or even fully replace bank credit and that the deterioration in the efficiency of bank credit allocation can be traced back to government interference. The research uses a heterogenous model considering both the rights for the property of corporations and the geographical extent of environmentally friendly development. Group analysis is used to investigate the effect of the sustainable instrumental credit policy by classifying businesses according to their ownership composition and GDI. Third, the research uses PSM for multidimensional data, integrating entropy balancing and DID approaches to accurately assess policy outcomes and provide fresh perspectives on assessment difficulties.

The remainder of this paper is structured as follows: Section 2 analyses the related existing that define the nexus between debt financing cost and green credit policy for polluting enterprise. Section 3 presents the theoretical assumptions research assumptions. It elaborates the category of industries involved in poulltion activities and involved in green credit policy framework. Section 4 describes the data and methods and the Difference-in-Differences methodlogy used for empirical analysis. Section 5 shows the discussion and empirical findings with the results of descriptive and PSM-DID analysis. Section 6 states the conclusion and policy implications of the study based on green credit policy and debt financing cost of heavily pollutant enterprises.

2. Literature review

There are numerous conventional and conventional factors like monetary policies and bank credit policies affect the investment and financing behaviors of enterprises especially green credit. Examined the effect of green credit policy on debt financing cost of heavily polluting enterprises. The results of the study shows that green credit policy directly increase the financing cost of heavily polluting enterprises.

To reduce the environmental risks, there is need to revise and implement green credit policies and its long term affects. Enterprises without green policies at high risk as compared to green enterprises. One simple solution, reduce the amount of loan by the financial institutions but extends more lean to green enterprises. Green credit legislation can reduce the short term financing for long term investment. Research reveal there is mediating effect between size of short run and level of investment thereafter the government subsidies can weakens the relation between short run financing for long term investment and green credit legislation [18,19]. There are policy concern for heavily polluting firms regarding financing in presence of green credit legislation to reduce short term financing and over-investment to fill the gap of business financing and investment. Filling such gap under credit risk, credit rent seeking problem can solve enterprises business financing and promote consistency of green credit protocols [20–22].

Extends the knowledge by discussing the nexus empirically between the varibles green credit development and debt financing cost of green enterprises [23]. Difference-in-differences model has been used in the existing literature and empirically examined that debt financing among highly polluting enterprises dropped significantly. Green credit development reduce the maturity period of two high enterprises. Few other studies proved that green credit policy only account for a small proportion of total credit line therefore the expected outcomes are far from desired goals.

The findings of the study are similar to the research design, data collection method and empirical analysis as reported in previous studies. It strengthen the comparability of the findings that in presence of green credit legislation, the cost of financing increases especially for the pollutant firms. The findings of the study further emphasizes the consistency patterns as green credit legislation has environmental consideration [24]. The study has not only contextual relevance but the theoretical consistency as theoretical framework corroborate the established theories in environmental economics, corporate finance and sustainable debt structure [25]. Last but not the least the meta analysis or systematic analysis of nexus between green credit legislation and business financing among polluting firms in China synthesize the results from multiple studies. By aggregating, the quantitative results of previous studies it can be demonstrated the consensus or divergence of findings within the existing literature.

In the context of impact of green credit legislation on business financing, the successful navigation of green credit landscape requires information, innovation and innovative network. It includes the availability of comprehensive data on environmental performance financial metrics and regulatory compliances. Global environmental challenges underscores the critical importance of integrating he sustainable practices in business financing especially among polluting firms [26]. In order to aling environmental objective with financial viability the transition toward green economy necessitate the innovative financing solution in polluting firms.

Various reports discussed the benchmarks of green credit portfolio in China. The 'Big Four[3]' between 2016 and 19 contributed around 240 billion US Dollar in the fossil fuel industry. The Industrial and Commercial Bank of China (ICBC) has a green loan worth 199 billion US Dollar one of the green to total loan at ratio 8 %. It is second largest loan in size in China Development Bank in 2019 with 9 % rise in Year over Year. According to ICBC, the 77 % of new electricity loan were issued which were genuinely clean energy loans. During the same period 9.8 billion US Dollar were issued green bonds. The historic background of ICBC shows the development of

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[3] The 'Big Four' are —Industrial & Commercial Bank of China, the China Construction Bank, the Agricultural Bank of China, and the Bank of China.

green banking where 1st green credit guidelines were issued in 2007. The ICBC joined the 'Green Finance Working Group' in 2015 and 2019 one of the largest overseas green bonds issued in 2019 worth 3.15 billion equivalent. The potential benchmark against industry average and non polluting firms financing rate can be evaluated and investigated. The environmental performace metric analysis such as carbon emission, pollutant discharge level and resource utilization efficiency of polluting firms can be examined under green legislation.[4]

H1. The hypothesis state that green credit legislation increases the cost of debt financing in heavily polluted enterprises. Thus the H1 provides an explanation for the reason how and how much green credit policy affects the business financing. Meanwhile the increasing trend of environmental risks augment the demand for informed decision regarding green credit policies and business financing.

3. Theoretical analysis and research assumptions

Sustainable Finance is an innovative combination of environmental and financial development that places equal emphasis on long-term viability. China has set lofty goals for sustainable transformation and development, and Sustainable Finance has emerged as a critical policy tool for achieving these goals. Most of the extant research focuses on gauging the development of Sustainable Finance by developing assessment frameworks. Sustainable Credit, securities, regulations, and investments are all standard components of such systems.

Researchers have investigated the effects of Sustainable Finance in numerous fields by building on these assessment approaches [27]. Several studies have looked at the impacts of Sustainable Finance on pollution and carbon emissions because it intends to encourage ecologically friendly projects and enterprises. One research looked at the effects of Sustainable Finance on industrial emissions in China and found that as Sustainable Finance developed, sulfur dioxide emissions decreased and investments in environmental protection rose. Another study using a geographic Durbin model found that although sustainable finance improves ecological quality in one region, it may have negative consequences for provinces nearby. Another research indicated that Sustainable Finance is crucial in cutting down on carbon emissions, which in turn helps sustainable development tremendously. Sustainable finance has also been shown to promote general economic growth. Another study used a geographical econometric model to show that sustainable finance has beneficial economic and spatial spillover effects.

In addition, the impact of Sustainable Finance on energy advancement has been investigated in the literature. Some research has shown that fostering Sustainable Finance may help cut China's coal usage and boost the country's sustainable energy growth. The evolution of China's energy landscape is greatly influenced by sustainable financing regulations, which have been found to promote the development of renewable energy sources favourably. There is a balance between promotion and inhibition in the influence that Sustainable Finance has on local energy intensity, as seen by the inverted U-shaped pattern [28]. Sustainable Finance has been shown to improve energy efficiency, which in turn helps ensure long-term fiscal viability.

Commercial Credit is an essential alternative to traditional bank loans since businesses often turn to it when facing demands for direction [29]. Regarding business credit, not paying on time might mean losing access to vendor cash discounts and straining relationships with those vendors. Companies often prioritize bank loans and other forms of external funding because of this [30]. Commercial Credit is an alternate source of financing for businesses during elevated operational risks and restricted bank credit conditions. Long-term partnerships between suppliers and enterprises provide distinct benefits in terms of data, including insights about company operations, financial stability, repayment capacity, and competitive standing in the sector [31] that are unavailable from banks. Commercial Credit is a viable alternative to traditional bank loans because of the informational benefits provided by trade partners with such advantages and the customary buyer-seller relationship. Retail Credit, instead of bank credit, is a popular choice for businesses working in locations with varying regulatory climates. This alternate strategy, however, may need more investment money.

The alternate connection between financial institutions and commercial Credit is intricately intertwined with the maturity structure of financing. Businesses often turn to retail Credit when access to traditional bank loans becomes more complex, and vice versa when bank lending loosens. Bank credit is more suited for short-term financing than commercial Credit because of the availability of other financing options [32]. The substitution theory states that when conventional sources of capital are scarce, businesses will turn to commercial lending. Suppliers are more likely to give short-term funding due to information asymmetry, using their knowledge advantage to limit the risk of default by borrowers. Therefore, the following theory is advanced in this investigation:

The research also considers the diversity of Sustainable Credit corporate property rights. Previous studies (Liu et al., 2019) have demonstrated that various business structures react differently to Sustainable Credit rules. State-owned enterprises (SOEs) play a more central role in implementing government programs, getting more excellent government assistance, and having access to more advantageous financing facilities than NSOEs. They show a more committed partnership with government programs and a greater adherence to guidelines.

The financial advantages of SOEs, especially highly polluting state-owned businesses, may be weakened by external pressure from Sustainable Credit regulations. SOEs have better access to credit resources, tax benefits, and government subsidies than NSOEs have because of their political ties and government credit support. This makes it harder for NSOEs to be approved for Credit. Given the close relationship between local government interests and the goals of Sustainable Credit guidelines, cities are increasingly asking banks to limit Credit to state-owned heavy polluters based on property rights to protect public health. When faced with the liquidity obligation imposed by sustainable credit laws, SOEs may more easily seek alternative financing thanks to their many available financing channels

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[4] https://www.climatepolicyinitiative.org/publication/green-banking-in-china-emerging-trends/081220green-bankin-trends/.

and the confidence they have earned from banks about their repayment capabilities. And because of their low default risk in commercial Credit and substantial financial resources, SOEs may profitably expand their financing use. As a result, we suggest the following theory:

Unlike NSOEs, SOEs show a far more significant alternative financing reaction to the "sustainable credit guidelines."

The regional variability of Sustainable Credit-approved sustainable development levels is also considered in the research. The study categorizes areas based on their sustainable development index since listed firms are registered. This categorization divides the sample into three groups according to their sustainable development index score. The Sustainable Development Index assesses a region's economic, environmental, resource-related, and governmental policy performance. Regions with a below-average Sustainable Development Index (LTA) typically experience elevated pollution levels and insufficient resources for environmental protection.

In these regions, local governments grapple with preserving the environment and reducing emissions while adhering to sustainable development principles. Consequently, businesses with lower GDI may encounter a more pronounced inhibitory effect on their investment and financing activities due to the impact of Sustainable Credit guidelines. Sustainable Credit may exert less effect on business investments in regions with above-average GDI. This analytical framework leads to the formulation of the following hypothesis:

Hypothesis 3 posits that all buseiness operating with below-average Sustainable Development Indices (LTA) are more likely to receive the significant response to "sustainable credit guidelines". Based on through alternative financing mechanisms compared to those operating in regions with above-average Sustainable Development Indices (HTA).

The sample selection followed a rigorous methodology to ensure the highest data quality and encompass A-share listed businesses from 2009 to 2021, primarily consisting of enterprises in highly polluting sectors such as thermal power generation Table 1.

4. Research design

4.1. Sample and data

This study utilized China's A-share listed firms from 2009 to 2021 as the research sample. The polluting companies were considered the experimental group, while the remaining companies served as the control group. The sample data are constrained within this timeframe to mitigate the influence of previous green credit rules enacted in 2007 and 2008. By controlling the sample interval from 2009 to 2021, we can isolate and measure the net effect of green credit regulations. However, if there is sequence correlation when employing the DID technique, it will cause the standard deviation of the estimator to be underestimated. This, in turn, will result in a bigger value for the T statistic and an exaggerated rejection of the null hypothesis. Hence, data that covers a significant duration may give rise to issues linked to sequence, which can be mitigated by limiting the sample to the year 2021. The sample underwent additional processing according to the following steps: (1) Companies that received special treatment during the research year were excluded; (2) Companies in the financial industry were excluded from the sample; (3) Samples with missing variables were excluded; (4) All continuous variables were adjusted to the 1 % and 99 % quantiles annually through winsorization. A total of 14882 observations were collected, with 2184 observations in the experimental group and 6126 observations in the control group.

Double-difference models are frequently employed for quantitative assessment of public policies. Two distinct sets of modifications have been derived by comparing the differences before and after the implementation of the policies. Once the initial difference is accounted for, the diversity among individuals remains constant over time and can be eliminated. The second difference is applied to the two groups of changes in order to remove the increase in changes over time. Ultimately, the overall impact of implementing the policy can be determined. Furthermore, the estimate outcomes of double-difference models are heavily reliant on the choice of the control group. To ensure the reliability of the findings, this article employs the propensity score matching method to match the control group with the contaminated samples. This involves identifying individuals in the control group who have similar characteristics to those in the experimental group, thereby reducing sample selection bias and ensuring that the balance hypothesis holds between the two groups. We conducted a regression analysis using the dual probit model to compare the experimental group and the control group. We matched the experimental group with the control group based on the propensity score value, selecting the control group with the closest matching probability value. Following the completion of the processing, a total of 14824 observations were acquired, with 2184 belonging to the experimental group and 6126 belonging to the control group. In order to ensure the dependability of the propensity score matching outcomes, we performed a balance test.

Table 1
Industry categories.

Thermal power	Mining
Steel	Chemical industry
Cement	Petrochemical
Electrolytic aluminium	Pharmaceuticals
Coal	Light Industry
Metallurgy	Textile
Building materials	Leather making

4.2. Model and method

The DID model is frequently employed for policy evaluation [5] to establish causal relationships. In the context of this research, the "sustainable credit guidelines" are treated as a completely exogenous event, unaffected by any single organization's actions, akin to a natural experiment. However, the selection is not random due to inconsistent sample categorization methods, and there is a distinction in businesses that might violate the common trend assumption. The PSM-DID model was introduced to address this issue [33].

The PSM method generates propensity score values, which the treatment group uses to select a control group most likely to yield similar outcomes. To ensure the accuracy of the PSM technique, achieving a standard deviation absolute value of less than 20 % after matching is recommended, a guideline proposed by Ref. [32]. Following this guideline, there is no statistically significant difference between the treatment group and the control group in any of the variables after the matching process, as the standard deviations of the variables in both groups have been significantly reduced. This demonstrates that the matching variables and techniques used for this study are appropriate and that their matching estimate results are trustworthy. The components used to determine the distinction-in-difference estimator (DID) are as follows in Eq. (1), Eq. (2) and Eq. (3):

$$ll\_it = \beta\_0 + \beta\_1 \ Treated\_i \times After\_t + \gamma Control\_it + \delta\_i + \lambda\_t + \varepsilon\_it \tag{1}$$

$$lll\_it = \beta\_0 + \beta\_1 \ Treated\_i \times After\_t + \gamma Control\_it + \delta\_i + \lambda\_t + \varepsilon\_it \tag{2}$$

$$ccf\_it = \beta\_0 + \beta\_1 \ Treated\_i \times After\_t + \gamma Control\_it + \delta\_i + \lambda\_t + \varepsilon\_it \tag{3}$$

The company's liquidity liability in year t is denoted by $llit$, its illiquid liabilities by $lllit$, and its commercial credit financing in year t by $ccfit$. The value of the treated group variable is one for firms that produce a lot of pollution (HP) and zero for those that don't. The dummy metric In the DID model, the interaction term Treated Afteri t is essential since Afteri t is equal to one after the event and zero before it. What we mean by "control" here is a group of factors that may be altered at the company's level. An individual firm's constant influence, denoted by i, and a continuous effect over time, indicated by t. Finally, it considers the random perturbation term.

5. Empirical findings

5.1. Descriptive statistics and parallel trend test

Table 2 presents comprehensive descriptive statistics for the entire sample. Notably, the illiquid liabilities of HP companies have remained relatively stable following the introduction of the "sustainable credit guidelines," NHP (Less Highly Polluting) companies have experienced a statistically significant increase of 0.02 percentage points, reaching the 1 % significance level. Similarly, the commercial credit for HP businesses has seen a statistically significant uptick of 0.022 at the 1 % significance level, whereas NHP firms have witnessed a comparatively minor increase. Consequently, it becomes imperative to investigate the policy's impact. The parallel trend assumption is pivotal in establishing causation through the Difference-in-Differences (DID) method. It is evident that, for the most part, a similar trend assumption holds within the sample. Additionally, the study incorporates firm-level characteristics as control variables in the regression analysis to mitigate the influence of potential confounding factors.

5.2. Analysis of benchmark regression results

Benchmark regression is a form of regression analysis that serves as a standard or reference point for comparing the impacts of various variables or policies. Benchmark regression involves evaluating the effect of a treatment or policy intervention by comparing the treated group to a control group over a period of time. Policy evaluation frequently employs this method to assess the efficacy of a policy by examining alterations in the outcome variables. Benchmark regression encompasses a range of regression models, including

Table 2
Descriptive statistical consequences.

Variable	Sample				HP enterprises			NHP enterprises		
	n = 14824				n = 1421	N = 2184		n = 2162	N = 6126	
	Mean	Std. dev.	Minimum	Maximum	Pre-policy Mean	Post-policy Mean	MeanDiff	Pre-policy Mean	Post-policy Mean	MeanDiff
Llit	0.406	0.486	−0.084	24.462	0.288	0.264	0.006***	0.482	0.404	0.026***
lllit,	0.004	0.222	−0.082	20.600	0.020	0.020	0.000	0.086	0.006	−0.020***
ccfit	0.022	0.260	−000.860	00.268	0.006	0.028	−0.002***	−0.006	0.026	−0.044*
Size	22.408	0.448	04.008	28.626	22.082	22.806	−0.626***	20.664	22.480	−0.806***
Growth	2.208	66.886	−4.482	4882.408	0.004	0.086	−0.060**	0.682	2.460	−0.666
Lev	0.424	0.466	−0.084	28.448	0.428	0.402	0.026***	0.468	0.408	0.068***
Cf	0.008	0.288	−2.604	26.600	0.006	0.006	0.000	0.004	0.000	−0.006
Roa	0.026	0.042	−40.288	008.266	0.024	0.022	0.002	0.020	0.044	−0.024
Soe	0.600	0.488	0.000	0.000	0.682	0.682	0.000	0.468	0.468	0.000

Note: Statistical significance of coefficient of the study stands at the 10 %, 5 %, and 1 % levels, respectively.

as simple linear regression, multiple regression, and more intricate econometric models like Difference-in-Differences (DID), Propensity Score Matching (PSM), or Instrumental Variable (IV) regression. The most important feature is that it establishes a standard for comparison, which enables researchers to separate the impact of the policy or treatment from extraneous variables. Benchmark regression analysis encompasses more than just multiple regression; however, multiple regression can be included as a component of it. Multiple regression is employed when many independent factors impact the dependent variable. Multiple regression in benchmark regression allows for the control of many confounding factors, enabling the isolation of the specific impact of the treatment or policy intervention. Our study's utilization of the PSM-DID model is consistent with the principles of benchmark regression and inclined with study [34] that uses benchmark regression to assess the influence of fiscal decentralization on green total factor productivity (GTFP) in China. The study creates a standard for comparison by analyzing the financial results of companies that pollute the environment before and after the implementation of green credit laws while also considering other factors that may influence the findings. This methodology enables a comprehensive evaluation of the policy's efficacy, serving as a benchmark for analyzing the alterations in corporate funding behavior resulting from green credit regulations.

As anticipated, adopting sustainable credit regulations is expected to significantly impact financing constraints for Highly Polluting (HP) industries, as outlined in the theoretical review and research assumptions section [35]. Table 4 presents the outcomes of the initial DID regression using models (1) through (3) without PSM, with results detailed in columns (1) through (3) for regressions without control variables and in columns (4) through (6) for those with control variables.

The results, statistically significant at the 1 % level, reveal that the sustainable credit strategy leads to a substantial decrease of approximately 1.35 percent in the illiquid liabilities of highly polluting (HP) enterprises. Simultaneously, liquid liabilities experience a noteworthy increase of 1.44 percent, also significant at the 1 percent level, while commercial credit witnesses a substantial growth of 1.76 percent. It shows a specific reduction in illiquid debt financing for HP companies following the implementation of the "sustainable credit guidelines." In contrast, commercial Credit and liquid debt utilization has notably increased in response to the stricter bank credit environment see Table 3.

5.3. Discussion

This section discusses the potential robust analysis, explores the Propensity Score Matching Difference-in-Differences dynamics of green credit policy, green credit development heavily polluting enterprises. It further discusses discusses the heterogeneity of property rights, heterogeneity of spatial sustainable development, asymmetric effects of green credit policy and green credit development on Chinese polluting firms.

5.3.1. PSM-DID results
Highlighting the crucial role of integrating digital technologies like artificial intelligence and its impact of green credit legislation on business financing enables more precise assessment of financing outcomes for polluting firms in China. Meanwhile discussing the relevance of agent based evolution system transform the industry such as transition from traditional to green and intelligent business models. For future consideration the applicability of findings digital technology and green legislation address the challenges and opportunities in sustainable finance and environmental governance.

The PSM-DID is aligned with digital technologies, green credit legislation and building material industry to green intelligent BMI as its helps to understand the cause and effect of the nexus. The DID model facilitate the analysis by incorporating digital indicator and comparing the change in outcomes like affected by green credit legislation and not affected groups over time. A heterogeneous effect on different kind of polluting firms with variation in size, industry and technological capabilities.

In this study, we employ the PSM-DID model to mitigate endogeneity issues and enhance the precision of our analytical results. This approach is chosen because the outcomes of the conventional DID model are influenced, which can introduce estimation biases, as [36] noted. The requirement for a successful match is that SD should be less than 20 %. Following matching, the control and treatment groups exhibit significantly reduced standard errors for each variable. Key variables have all experienced substantial decreases in their respective common errors, ranging from 10.4 % to as much as 81.4 %, indicating tight alignment of variable characteristics between the two sample groups post-matching. This adherence to the balancing assumption of the DID model, where the absolute value of standard errors falls below 20 % after matching, indicates a successful matching process. The results of the PSM-DID model are presented in Table 4. Due to the sustainable credit program, highly polluting (HP) entities observed a decrease of 0.30 percentage points in their illiquid liabilities. However, this program had a notable adverse impact on the liquidity liabilities and ccft enterprises, increasing them by 0.22 percent and 2.02 per cent, respectively. These findings suggest that in response to banks' increasing selectivity in loan disbursements, businesses facing loan difficulties are turning to their suppliers for financial support. Demand-driven commercial Credit is emerging as an increasingly vital complement to conventional bank loans. Complex dynamics in long-term relationships between businesses and their suppliers and information asymmetry are frequently cited as primary factors contributing to this phenomenon. Commercial Credit is commonly extended by upstream suppliers who provide goods to businesses before receiving payment. Please repay the loan promptly to avoid the business losing cash discounts and jeopardizing its relationship with the supplier. Consequently, commercial Credit makes it more expensive for polluting companies to secure financing see Table 4.

The sustainable credit strategy must account for managing HP enterprises and close the gap efficiently. Heavy polluters (HP) often go to their supply chain partners for financial backing when access to financing is limited by government regulation. Many businesses rely on commercial loans from upstream suppliers in commodities before payment because of knowledge asymmetry and long-standing cooperative trade relationships. On the other hand, retail credit in the form of cash before products is occasionally obtained by businesses from their final consumers.

Table 3
Benchmark outcomes.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	llit	Lllit	ccfit	Llit	lllit	Ccfit
Treated_after	1.00042	−1.0242***	1.0004**	1.0044***	−1.0024***	1.0066***
	(1.0082)	(1.0042)	(1.0046)	(1.0044)	(1.0046)	(1.0042)
Size				−1.0260***	1.0202***	1.00262
				(1.0020)	(1.0022)	(1.0040)
Growth				−8.42 e−04	1.02 e−06	1.00204**
				(1.0006)	(1.0006)	(1.0000)
Lev				0.686***	1.220***	1.204***
				(1.0024)	(1.0042)	(1.0068)
Cf				1.0020**	−1.0028*	1.0682***
				(1.0062)	(1.0062)	(1.0088)
Roa				1.0042	−1.0420**	1.00644
				(1.0042)	(1.0064)	(1.0222)
FE Firm	Yes	Yes	Yes	Yes	Yes	Yes
FE Year	Yes	Yes	Yes	Yes	Yes	Yes
N	04,824	04,800	04,804	04,826	04,802	04,806
R-squared	0.024	0.020	0.020	0.660	0.068	0.086

Table 4
PSM-DID consequences.

Variables	(6)	(8)	(8)
	Llit	lllit	Ccfit
Treated_after	1.0022**	−1.0040**	1.0202***
	(1.0040)	(1.0046)	(1.0066)
Size	−1.0262***	1.0084***	1.00482
	(1.0022)	(1.0046)	(1.0044)
Growth	−1.000044	1.000682	1.00282**
	(0.0000)	(1.0000)	(1.0008)
Lev	1.680***	1.220***	1.084***
	(1.0046)	(1.0086)	(1.0204)
Cf	−1.00646	1.00822	1.0080
	(1.0088)	(1.0024)	(1.0068)
Roa	1.0200	−1.0460**	1.000006
	(1.0220)	(1.0284)	(1.0226)
Constant	1.604***	−1.424***	−1.084*
	(1.0604)	(0.000)	(1.006)
FE firm	Yes	Yes	Yes
FE year	Yes	Yes	Yes
N	6622	6622	6622
R-squared	0.646	0.064	0.086

The PSM-DID and the reference DID models provide somewhat different regression coefficients, but they agree with the findings' general trend and statistical significance. This result is consistent with hypothesis 1, which states that "sustainable credit guidelines" cause a considerable increase in liquid debt financing and a significant decrease in illiquid debt financing for the most polluting enterprises.

5.4. Robusteness test

This section discusses the potential robust analysis, explores the transmission mechanism of green credit policy, green credit development and green enterprises and "two-high" enterprise financing and further.

5.4.1. Placebo test
This is used to ensure reliable findings in scientific studies. Its goal is to ascertain if the influence of the policy in question is real or the result of chance or other less tangible variables. A "fake policy incidence time or experimental group" is created and analyzed to determine whether a policy's impact can be discerned. Suppose a policy effect is still shown in the placebo test. In that case, other unmeasured factors may impact the financial results, casting doubt on the validity of the policy impact in the benchmark regression. This article used bootstrapping to randomly allocate experimental groups within the total sample, simulating a placebo test to reduce the chance of confounding by other unobserved factors. To ensure the reliability of the results, we randomly assigned 500 subjects to each group and displayed the coefficient estimates of the interaction term together with their associated *P*-values. The placebo effect coefficient estimates are all close to zero, and none are statistically significant at the 10 % level of certainty. It's important to note that

the test results do not include the estimations of the baseline regression. This suggests that the results of this research were not influenced by factors that were not directly measured.

The Placebo effect has metaphorical[5] connection with impact of green credit legislation on business financing of the poluuting firms [37,38]. The Placebo effect is used to assess the true impact of policy intervention such as green/sustainable credit legislation by comparing the scenario where the policy is not in place or has no effect. In the context of green credit legislation and business financing of polluting firms, researchers might use placebo tests or similar methods to control for other factors that could influence financing behaviour [39–41]. For example, they might compare the financing patterns of polluting firms before and after the introduction of green credit legislation, while also considering changes in economic conditions, market trends, or other regulatory changes [42].

5.4.2. Replacement of samples

The study reworked the regression analysis by substituting the sample data to address potential biases stemming from sample selection. Employing the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method, which ranks pollution levels, we categorized businesses into high- and low-polluting groups. Subsequently, the most recent sample data underwent a two-way fixed-effects regression analysis see Table 5.

The results revealed that the implementation of the sustainable credit strategy had a direct impact on reducing the illiquid liabilities of highly polluting enterprises, resulting in a decrease of 0.26 percentage points. Furthermore, the program positively affected industrial Credit and the liquidity liabilities of enterprises with high pollution levels, reaching statistical significance at 10 %.

5.4.2.1. Matching samples. This study used an entropy balancing approach to equate the control and experimental groups. We utilized the entropy balance load value computed by considering the first, second, and third moment of covariates as constraints for matching. Initially, there were notable differences in variables between the experimental and control groups. However, the application of entropy balancing matching significantly reduced these disparities. Subsequently, we conducted bidirectional fixed-effects regression using the matched data to derive the outcomes presented in Table 6. Based on these findings, it can be deduced that implementing the sustainable credit policy substantially impacted the financial landscape of highly polluting (HP) enterprises. Specifically, it led to a remarkable increase in their liquid liabilities and commercial Credit while concurrently reducing their illiquid liabilities by 0.86 percentage points. These results hold statistical significance and align with our previous conclusions.

5.5. Heterogeneity of property rights

The interplay between state-owned enterprises (SOEs) and non-state-owned businesses (NSOEs) in China is distinct due to the nation's institutional history. As demonstrated in Table 7, highly polluting firms with substantial state ownership have witnessed a notable reduction of 1.20 % in their illiquid liabilities directly attributable to implementing the sustainable credit program. Conversely, non-state-owned, highly polluting firms do not face the same limitations when seeking financial support; hence, they are not subject to equivalent constraints.

SOEs often find negotiating supplier agreements more straightforward because of their extensive scale and access to more financing options than NSOEs. Moreover, SOEs are more likely to have access to alternative sources of financing, mainly because local governments often impose less stringent environmental controls on them. Consequently, in the aftermath of the sustainable credit strategy, SOEs now carry significantly higher obligations for liquid assets and commercial Credit. Thus, supporting Hypothesis 2, it is evident that the policy exerts a more pronounced influence on SOEs than on NSOEs.

5.6. Heterogeneity of spatial sustainable development

When examining the registered locations of the chosen publicly traded companies, significant differences exist in the financial support policies provided by local financial institutions to each firm. These discrepancies arise from variations in the levels of sustainable development across the regions where these companies are registered. Consequently, the responses of these listed firms to the sustainable credit program exhibit diversity. As a result, it becomes essential to consider the impact of regional diversity when evaluating the Sustainable Development Index for Chinese provinces. GDI in China comprises three principal indicators, nine sub-indicators, and sixty-two tertiary indicators. This comprehensive set of metrics encompasses factors such as sustainable economic growth, environmental resource capacity, and governmental policy support to gauge the extent of sustainable development.

Table 8 illustrates the considerable impact of the sustainable credit program on the financing obligations of highly polluting (HP) enterprises in regions characterized by varying levels of GDI. Specifically:

The illiquid liabilities of HP firms have been lowered by 1.94 percent in regions with low GDI areas thanks to the sustainable credit policy. At the 5-percent threshold of significance, this decrease becomes evident. At the 5 % significance level, the sustainability financing plan has significantly raised the liquidity liabilities of highly polluting enterprises (HP) in regions with low rates of sustainable development. However, polluting companies' illiquid debts respond poorly to the environmentally friendly financing approach in places with substantial sustainable growth.

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[5] Methaphorical connection is used 'stands for' or 'symobize' anything. Generally speaking it is used to compare or equate two indirectly related things.

Table 5
Robustness check for changing samples.

Variables	(07)	(08)	(09)
	llit	lllit	Ccfit
Treated_after	0.0220***	−0.0026**	0.0008*
	(0.00820)	(0.00448)	(0.00626)
Size	0.0408***	0.0624***	0.0002
	(0.00260)	(0.00240)	(0.00280)
Growth	0.0480***	0.0062***	−0.0002***
	(6.88e-04)	(6.46e-04)	(0.84e-04)
Lev	0.8428***	0.2826***	0.0262***
	(0.0064)	(0.0024)	(0.0048)
Cf	−0.0048	−0.0008	0.0024
	(0.0046)	(0.00864)	(0.00888)
Roa	0.4840***	0.0628**	−0.0846***
	(0.0420)	(0.0242)	(0.0286)
Constant	0.064**	−0.022***	−0.264***
	(0.0624)	(0.0606)	(0.0684)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	8840	8840	8840
R-squared	0.624	0.280	0.062

Table 6
Regression results for entropy balancing and differential inference.

Variables	(10)	(11)	(12)
	llit	lllit	Ccfit
Treated_after	0.0240***	−0.00864*	0.0082***
	(0.00448)	(0.00484)	(0.00442)
Size	−0.0228***	−0.00442***	−0.00666***
	(0.000866)	(0.000686)	(0.000842)
Growth	0.00206	0.00262**	0.00602***
	(0.00204)	(0.00068)	(0.00224)
Lev	0.888***	0.226***	0.242***
	(0.0222)	(0.0202)	(0.0228)
Cf	0.0026	−0.0266**	0.0808***
	(0.0006)	(0.0026)	(0.0044)
Roa	0.0288	0.0004	−0.00220
	(0.0204)	(0.0264)	(0.0222)
Constant	0.420***	0.0422***	0.0440***
	(0.0008)	(0.00620)	(0.00882)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	04,826	04,802	04,806
R-squared	0.482	0.024	0.060

Table 7
The heterogeneity outcomes of organization belonging rights.

Variables	SOE			NOSE		
	llit	lllit	ccfit	llit	lllit	Ccfit
	(1)	(2)	(3)	(4)	(5)	(6)
Treated_after	0.0202***	−0.0220***	0.0224***	0.00482	0.0286	0.006
	(0.00488)	(0.00604)	(0.00660)	(0.00600)	(0.0262)	(0.020)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	8060	8046	8048	4644	4646	4648
R-squared	0.600	0.086	0.080	0.880	0.026	0.488

There could be a correlation between the higher concentration of polluting firms in areas with lower levels of sustainable development and the program's ineffectiveness. This finding supports the third interpretation, which proposes that the sustainable credit program has a more significant effect in areas where municipalities have adopted more excellent initiatives to limit pollution.

6. Conclusion and policy implications

6.1. Conclusion

Sustainable credit policy has been proven in the literature to affect businesses' debt financing structure and capital availability. Studies have shown that sustainable finance legislation may increase the debt financing capacity of environmentally from 2009 through 2021; this article examines the financial reaction to the sustainable credit program among businesses listed on the Shanghai and Shenzhen stock exchanges that operate in a highly polluting sector. We use Propensity Score Matching (PSM) to combine and analyze data from several dimensions. We use entropy balancing and the Difference-in-Differences (DID) technique to get more accurate evaluations of the effects of various policies and new perspectives on evaluating them. We also include corporate ownership rights (State-Owned or Non-State-Owned Enterprises) and the amount of sustainable development in a given area (High, Medium, or Low) into the twofold heterogeneity model. These inferences may be made:

Liquid and commercial Credit has increased while illiquid assets have decreased for the most polluting enterprises thanks to the sustainable credit strategy. Businesses have responded positively to the policy's alternative financing options, the sustainable Credit, in large numbers. Commercial borrowing has increased opportunity costs, administration expenditures, and lousy business debt costs. While short-term loans replace long-term borrowing, companies still incur these expenses when they keep accounts receivable. As a result, businesses will have to pay a higher interest rate on their financing due to the sustainable credit policy.

State-owned enterprises (SOEs) benefit more than non-state-owned enterprises (NSOEs) from the sustainable credit policy's reduced illiquid liabilities. This severely limits the ability of severely polluting SOEs to raise long-term Finance. However, as these severely degrading SOEs now have access to a wider variety of financing choices and higher liquidity, their debt and commercial Credit have expanded dramatically.

In areas with higher-than-average pollutants and less ecological capability, such as those with a Sustainable Development Index below the average (LTA), the "sustainable" credits standards" have an increasingly noticeable impact. While the "sustainable credit policy" has helped cut down on polluted businesses' permanent illiquid debts, competition from other forms of financing has altered the industry's financial architecture in ways that make effective credit regulation more difficult. China's sustainable credit strategy must be dynamic and ever-evolving to limit financing for polluting and harmful enterprises.

The integration of digital technologies and application of PSM-DID play crucial role in advancing the impact of green legislation on business financing of polluting firms in China. The transformation of building material industry to green intelligent BMI underscore the importance of business practices in reshaping sustainable finance and environmental governance. By leveraging the digital tools and analytical framework using PSM-DID model provide precise and effective assessment of financing outcomes.

6.2. Implications for policy

Sustainable Finance will emerge as a critical policy instrument during China's 14th Five-Year Plan to realize sustainable growth and construct an ecologically friendly and resource-efficient society. The role of sustainable finance with respect to green credit legislation is indispensable for business operation especially for heavily polluting firms. The results of the study resonate with study hypothesis and validated through PSM-DID modelling. Green credit legislation has transformed the mode and extent of financing for both polluting and non polluting industries in the light of emerging environmental considerations. The following policy recommendations stem from the analysis above:

There is utmost need to government revise clear and practical standards to improve sustainable credit laws. Banks and lending organizations focusing on environmental responsibility should know their legal duties regarding pollution through these rules. A regulatory system that aligns with sustainable credit rules should be established to ensure that sustainable loans are used for their intended purposes and to control the flow of sustainable credit funds effectively.

In order to combat climate changes, the policy makers and researcher prioritize the desgined the infrastructure based on sustainable financing. As this infrastructure is environmentally friendly and cost effective thus policymakers should thoroughly assess region's economic development level and financing decision in the light of environmental challenges. Financing decision which enlighten the green credit legislation emphasizes companies need to establish rigorous evaluation standards and back those standards

Table 8
The heterogeneity results of the spatial sustainable improvement index.

Variables	Enterprises in areas with high levels of sustainable development			Enterprises in regions with low levels of sustainable development		
	llit	lllit	ccfit	llit	lllit	Ccfit
	(1)	(2)	(3)	(4)	(5)	(6)
Treated_after	0.0004*	−0.00648	0.0086*	0.0082**	−0.0084**	0.0206**
	(0.00424)	(0.00464)	(0.00660)	(0.00642)	(0.00662)	(0.00844)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	8484	8464	8480	4422	4408	4408
R-squared	0.664	0.068	0.066	0.660	0.080	0.044

up with policy assistance. Effective enforcement of sustainable credit rules via fines and incentives is essential, but authorities also need to provide a way to measure the policies' effects. Companies ought to create a review mechanism to gauge the success of sustainable credit programs and construct a structure to identify environmental hazards.

Financial institutions, which serve as the key implementers of sustainable Credit, should carefully monitor the evaluation procedures and credit criteria used by enterprises with a high environmental impact. They need to make establishing sustainable credit policies easier, increasing access to sustainable credit financial products, and developing pricing methods considering different kinds of businesses. By doing so, we can guarantee the sustainability of sustainable credit policy results and direct financial resources toward sustainable enterprises and endeavours.

To reap the full benefits of the national sustainable credit scheme, businesses must improve their dedication to environmental preservation. More extreme commitment to ecological sustainability is encouraged via the initiative, particularly among the most polluting companies. To lessen their adverse effects on the environment, businesses should aggressively seek technological improvements and developments. This involves abandoning wasteful and energy-intensive industrial practices of yesteryear. As the need for environmental protection becomes more widely accepted, suppliers should pay closer attention to one another's sustainable and sustainable development initiatives and progressively include problems with pollution in their cooperation contracts.

The above study has strategic integration in light of managerial implication as it accounts for multilple dimension at the same time like green legislation, digital technologies and business financing. It necessitate the role of adopting agent based evolutionary system in managerial decision making which transform the traditional to green intelligent based model. Managers of heavily polluting firms can make informed decision regarding strategic planning, risk management and capital allocation. They can also identify and make rational decision on vulnerabilities of business financing.

The practical and social implication of the study reports proactive engagement with stakeholders essential for building trust, fostering transparency and promote social responsibility. By aligning the green legislation of business financing with environmental objectives and societal needs firms can enhance inclusive and sustainable development through social licence to operate. The transition toward green legislation in the light of digital technologies, heavily polluting firms can minimize their ecological footprint to combat climate changes and preserve ecological ecosystem thus benefiting the society as a whole.

Ethics approval and consent to participate

Not applicable.

Consent for publication

All of the authors consented to publish this manuscript.

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Data availability

We collected relevant data from World Bank open data available at https://data.worldbank.org/. For any further query on data, corresponding author at email address *hunaixin@sdu.edu.*cn may be approached.

CRediT authorship contribution statement

Naixin Hu: Writing – review & editing, Writing – original draft, Project administration, Conceptualization. **Umar Suffian Ahmad:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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