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CAN THE GREEN CREDIT POLICY PROMOTE GREEN INNOVATION IN ENTERPRISES? EMPIRICAL EVIDENCE FROM CHINA

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Abstract. The green credit policy (GCP) is an institutional framework aimed at guiding enterprises towards green transformation and promoting high-quality development, which serves as a crucial tool for supporting the establishment of a green technology innovation system. In this study, utilizing the green credit guidelines as a quasi-natural experiment and constructed a continuous difference-in-difference (DID) model, examines the impact of GCP impact on enterprise green innovation and its internal mechanisms by analyzing data from Chinese A-share listed companies between 2006 and 2021. Our findings indicate that the GCP had a significant impact on enterprise green innovation, inhibiting companies from independently developing green innovation while promoting joint green innovation with other institutions; These results were robust and consistent, even after conducting several sensitivity analyses; This mechanism indicate that the commercial credit plays an important regulatory role in the process of GCP affecting green innovation of enterprises and the financing constraints act as an intermediary factor in the process of GCP affecting green innovation. Based on our research, we offer policy recommendations aimed at improving the GCP and fostering a market-oriented green technology innovation system.

Keywords: green credit policy, green innovation, commercial credit, financing constraints.

JEL Classification: G21, G32.

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1. Introduction

In today's world, where global ecological and environmental challenges are at the forefront of discussions, and sustainable development remains a challenging task, green development has emerged as a pivotal theme in the realm of worldwide economic progress (Lee et al., 2022a; Lee & Lee, 2022). China, amidst its rapid economic expansion, is facing significant ecological and environmental issues. To address these pressing concerns, China has embarked on an admirable journey towards environmental stewardship, resulting in overall improvements to environmental quality. The establishment of an ecological civilization, the adoption of innovative development paradigms, and the promotion of green economic progress are essential for realizing sustainable development. While enterprises play a critical role in driving green innovation (GI), their primary focus on profit maximization often acts as a deterrent to engaging in sustainable practices. To overcome this challenge, the government has prioritized

the creation of a green and low-carbon circular economy, necessitating the formulation of a comprehensive GI framework. However, substantial costs, pronounced externalities, and elevated risks associated with GI pose formidable obstacles for enterprises (Lee et al., 2023b; Abakah et al., 2023), resulting in a noticeable lack of incentives for integrating green practices (Francis & Smith, 1995).

In order to tackle these issues, it is essential to have access to financial resources. Green finance has emerged as a vital link between environmental governance and the financial system (Taghizadeh-Hesary & Yoshino, 2019; Lee et al., 2023a). Green finance is instrumental in fostering the development of a green technology innovation system and ensuring adequate financial backing for ecological environmental governance. Green credit, a crucial element of green finance, can effectively address the challenges posed by high capital requirements and investment risks (Lee et al., 2023b; Wang et al., 2023), while simultaneously promoting sustainable development in enterprises (Sun et al., 2021).

Green credit policies (GCPs) mandate that banks and other financial institutions consider environmental factors when evaluating credit business conditions, and make adherence to environmental standards, pollution control, and ecological protection a key criterion for granting credit approval (Lv et al., 2023). The implementation of GCPs has established stringent guidelines for financial institutions to pursue green credit businesses and effectively mitigate environmental risks. As global environmental issues continue to escalate, GCP is emerging as a "top-down" environmental policy with immense potential for the future (Lee et al., 2023a). In the coming years, GCPs will continue to support sustainable development goals through financial means and foster a mutually beneficial relationship between the economy and environmental protection. Can GCPs effectively drive GI in enterprises? What are the internal mechanisms for action within these organizations?

The literature on the relationship between GCP and GI is particularly relevant to this study. Several studies have suggested that green investment can act as a catalyst for fostering firms' green technological innovation (Acemoglu et al., 2016; Aghion et al., 2016). GCP provides financial incentives as emphasized by Houston and Shan (2022), where companies with strong ESG performance have an easier time obtaining loans from banking institutions. This results in higher lending rates for polluting firms, thus increasing their cost of borrowing (Fan et al., 2021; Reghezza et al., 2022). It is evident that GCP will motivate enterprises to pursue green technological innovations (An et al., 2021; Nabeeh et al., 2021; Hu et al., 2021; Lu et al., 2022). Nevertheless, some studies have raised concerns that GCP may be a hindrance to enterprises' green technological innovation (Stucki et al., 2018). GCP can create a financial constraint mechanism, potentially increasing the cost of financing for polluting enterprises. This may result in a "crowding-out" effect on their research and development (R&D) and innovation funds, ultimately hindering the green technological innovation of these companies (Zhang et al., 2021a; Wen et al., 2021). Therefore, while numerous scholars have attempted to explore the relationship between GCP and green technological innovation of enterprises, a consensus has yet to be reached. It is imperative to clarify the impact mechanism of GCP in order to accurately identify its action path and measure its implementation effect.

This study aims to accomplish two significant objectives. Firstly, by utilizing the research methodology of the cutting-edge literature on green credit, we construct the indicators used

to measure the degree of influence of the treatment group by GCP as the core explanatory variables. This will serve as a foundation for subsequent empirical analyses to evaluate the effects of GCP. Secondly, this study investigates the micro-transmission mechanism of GCP on enterprises' GI by considering China's specific circumstances. To do so, it has chosen Chinese A-share listed companies from 2006 to 2021 as its research subjects and employed a DID model to examine the relationship and underlying mechanisms between GCP and GI.

The possible contribution of this paper compared to existing studies is:

Firstly, this study makes a significant contribution by providing novel empirical evidence that sheds light on the complex interplay between GCP and corporate GI. Previous research has primarily focused on examining the micro-level effects of GCP, analyzing enterprises' independent pursuits through the analysis of green patents' individual applications (Xing et al., 2021; Zhang et al., 2022a; Cui et al., 2022; Tan et al., 2022b; Wang et al., 2022; Lv et al., 2023). It is possible that GCP may have different effects on firms' independent and joint applied (granted) of green patents. However, the existing research has not fully explored the influence of GCP on firms' joint efforts in engaging in GI. Therefore, it is essential to delve deeper into this aspect to gain a comprehensive understanding of how GCP impacts various innovation approaches within enterprises. To address this research gap, our study utilizes four distinct indicators of GI – the quantity of green invention patents granted through individual applied, individual granted, joint applied, and joint granted by enterprises. Our findings indicate that GCP have a significant impact on the quantity of green invention patents granted through joint applied by enterprises, but they also inhibit independent GI by enterprises. This discovery not only enhances and broadens the academic comprehension of the economic ramifications of GCP, but also provides a novel perspective for examining their impact on enterprise GI.

Secondly, a significant contribution of this study is the meticulous construction of variables, which accurately measures the treatment group's exposure to GCP. This rigorous approach helps to identify the causal effect of the policy with greater precision. In existing literature, GCP is often considered as a quasi-natural experiment that reduces the challenges associated with reverse causality and measurement errors caused by using a single indicator to measure policy effects. However, most studies tend to rely heavily on industry-level variation as a proxy to assess firms' exposure to GCP (Yao et al., 2021; Cui et al., 2022; Zhang et al., 2022b; Gao & Liu, 2023; Sun & Zeng, 2023). In contrast, this paper introduces a novel variable that captures the spectrum of GCP's influence, quantified as the weighted average of pollutant emission reduction levels across diverse industries. This innovative variable is integrated within the framework of the traditional DID methodology, culminating in the formulation of an interaction term between the two. This interaction term assumes the mantle of the core explanatory variable, signifying the degree of GCP's impact on industries constrained by its directives[1]. This distinctive approach not only enriches the panorama of research pertaining to the micro-level repercussions of GCP, but also pioneers fresh avenues for subsequent inquiries aimed at comprehensively assessing the effects and implications of GCP.

[1] This method can effectively avoid situations where non-restricted industries under GCP are classified as the treatment group and, at the same time, can depict the degree of policy influence on the treatment group (industries with strict and substantial pollution reduction levels experience more significant impacts on their internal enterprises).

Thirdly, this study delves comprehensively into the intricate mechanism underlying the influence exerted by GCP on the landscape of enterprises' GI. While existing studies have undertaken a multifaceted analysis of the micro-level transmission mechanism of GCP on GI, exploring facets such as financing constraints (Hu et al., 2021), total factor productivity (Cui et al., 2022), ownership concentration (Zhang et al., 2022b), and the peer effect of GI (Tan et al., 2022b), they inadvertently overlook a comprehensive grasp of enterprises' behavioral choices within the purview of this policy. To bridge this gap, our research embarks on a nuanced exploration of corporate behavior's role in mediating the impact of GCP on GI, honing in particularly on the prism of commercial credit (Lv et al., 2023). This strategic approach unveils the intrinsic logic and tangible outcomes of GCP's role in shaping enterprises' pursuit of GI. Furthermore, our study takes a significant advancement in deepening our understanding of the diverse nature that characterizes the influence of GCP on enterprise GI. This endeavor is achieved through the meticulous consideration of diverse factors, ranging from the external business milieu and equity nature to executive education. This multi-dimensional analysis adds a layer of depth to quantitative research within this domain. In summation, our paper stands as a repository of empirical evidence, meticulously fostering an objective evaluation of the substantive impact stemming from the implementation of GCP. Additionally, it serves as an invaluable benchmark, poised to inform and guide the enhancement and evolution of green financial policies in the foreseeable future.

2. Literature review

2.1. Economic effects of GCP

Designed as a quintessential "top-down" government policy, GCP assumes a dual role of both facilitating resource allocation and advocating for risk management (Wen et al., 2021; Wang & Wang, 2022). On the one hand, GCP can effectively guide and mobilize financial resources towards green and low-carbon areas (Xu & Li, 2020). For instance, He et al. (2019b) highlighted that GCP reduces the cost of enterprise financing and enhances the efficiency of enterprise loan resource allocation. However, some research has suggested that GCP have a "disciplinary" and "warning" effect on high-polluting enterprises by directing credit funds towards the green sector (He et al., 2019a). This can directly increase the financing thresholds and standards for high-polluting enterprises, limiting their financing options and increasing their costs (Fan et al., 2021; Reghezza et al., 2022). Additionally, it can exacerbate the financial constraints faced by heavy-polluting enterprises (Liu et al., 2019; Zhou et al., 2022). Fan et al. (2021) suggest that GCP can lower the cost of corporate debt financing and optimize the debt maturity structure, resulting in a significant financing penalty effect. Zhang et al. (2021a) assert that GCP has both a significant financing penalty effect and an investment inhibition effect on the medium- and long-term investment and financing decisions of polluting enterprises.

On the other hand, the potential environmental pollution risks faced by bank-type institutions during loan approvals have also been increasing. The implementation of GCP has prompted banks to incorporate corporate environmental protection disclosures as a criterion for credit decisions, effectively mitigating loan risks (Tiwari et al., 2022). Additionally, Yin

et al. (2021) analyzed the impact of GCP on bank profitability and found that it can improve operational performance and cost efficiency.

Several studies have also confirmed the influence of GCP on corporate investment and financing behavior (Wang et al., 2020; Wen et al., 2021), credit resource allocation (Tombe & Winter, 2015), total factor productivity of corporations (Cui et al., 2022), ESG performance (Gao & Liu, 2023), and firm performance (Yao et al., 2021). Specifically, the policy has been found to result in effective credit financing inhibition for enterprises, improved total asset return for commercial banks, and reduced credit risk through the imposition of financing penalties and investment inhibition (Scholtens & Dam, 2007; Luo et al., 2021).

2.2. Environmental effects of GCP

As a new type of environmental policy, scholars have conducted studies on the environmental effects of GCP in response to increasingly severe environmental pressures. These studies have confirmed that GCP has a significant impact on various aspects of the environment, including air quality (Su et al., 2022), enterprise energy use efficiency (Tan et al., 2022a), enterprise emission reduction (Zhang et al., 2021a; Zhang et al., 2022; Sun & Zeng, 2023), corporate green productivity (Lv et al., 2023), and corporate environmental performance (Zhang et al., 2021a; Su et al., 2022a). For instance, Fan et al. (2021) utilized Chinese micro-data to demonstrate that GCP increases the loan costs of firms that default on their environmental obligations, which ultimately leads to a reduction in pollution emissions. Similarly, Lv et al. (2023) conducted an analysis of the impact of GCP on the green productivity of heavily polluting firms and found a positive correlation between the two. Lee et al. (2022b) conducted a study to examine the effect of GCP on promoting the green transformation of highly polluting firms from the perspective of carbon emissions reduction. The study concluded that GCP is the primary driving force in reducing carbon intensity among enterprises.

2.3. Green innovation effects of GCP

Green credit, as a crucial component of green finance, plays a vital role in facilitating the attainment of both economic and environmental benefits. As a form of sustainable investment and financing, GCP have a significant impact on both macroeconomic development and microeconomic operations. The literature has established that GCP have a positive effect on promoting GI at the national or regional level (Zhang et al., 2021b; Lee et al., 2023a). Lee et al. (2023b) conducted a study using panel data of Chinese cities to evaluate the impact of GCP from the perspectives of GI and green space for the first time. The study found that GCP have a significant positive effect on promoting urban GI and green space.

At the micro level, research based on specific subjects is more commonly observed at the enterprise level and tends to support the notion of promoting GI (Hu et al., 2021; Xing et al., 2021; Zhang et al., 2022b; Lv et al., 2023). Cui et al. (2022) suggested that GCP has a significant impact on firms' green technological innovation mainly through total factor productivity. Tan et al. (2022b) noted that the cohort effect of green technological innovation triggered by GCP significantly improves the quality of firms' GI. Wang et al. (2022) investigated the impact of GCP on the quality of firms' GI and concluded that GCP enhances the quality of GI.

The existing literature has provided a solid foundation for exploring the micro-level effects of GCP, yet there are still several areas that require further investigation: (1) Research perspectives: there is a significant difference in the impact of government policies on enterprises' independent and joint application (obtaining) of green patents. However, most existing literature has only examined the micro effects of GCP from the perspective of enterprises' independent application (obtaining) of green patents, without delving into the relationship between GCP and enterprises' joint application (obtaining) for GI. (2) Empirical research and treatment group identification: the basic idea of the DID model is to use the variation in the intensity of policy impact between the treatment and control groups to identify the average treatment effect. However, existing literature mainly uses industry-level variations as indicators of the degree to which enterprises have been impacted by GCP. Therefore, further research is needed on how to identify the appropriate treatment group for this model. (3) Dynamic firm responses: enterprises' responses to GCP are not static and may vary over time. Firms may use buffering or facilitating mechanisms to regulate the actual impact of GCP on their GI. Therefore, it is important to explore in depth the role played by firms' behavior in determining the effects of GCP on GI.

3. Policy background and research hypothesis

3.1. Policy background

In 2007, the Chinese government officially introduced the concept of green credit through their "Opinions on Environmental Protection Policies and Regulations to Prevent Credit Risks". This was followed by the establishment of the Green Credit Guidelines in 2012, which marked a significant milestone in the implementation of GCP in China. The comprehensive framework established by these guidelines laid the groundwork for the development of the GCP system in the country. The "Guidelines" outlined specific regulations governing the issuance of green credit, requiring financial institutions such as banks to restrict loans or withhold credit from industries or projects that exhibit high pollution and substantial energy consumption. In contrast, these institutions were encouraged to provide credit support to green industries and projects that prioritize environmental conservation and pollution mitigation. The implementation of GCP has yielded clear and significant policy effects, making data collection and measurement relatively straightforward when compared to other green finance instruments like green bonds, green funds, and green insurance. Moreover, the well-defined classification of industries with high pollution and energy consumption by the former China Banking Regulatory Commission in 2014 guided the banking sector towards developing green credit initiatives. Consequently, the "Guidelines" of 2012 effectively constitute a quasi-natural experiment, which allows researchers to utilize the DID methodology to meticulously examine and analyze the impact of GCP on GI.

3.2. Theoretical analyses and research hypotheses

Neoclassical economics contends that environmental protection policies result in increased private production costs and decreased firms' competitiveness, ultimately nullifying any positive societal impact from these measures. Porter's hypothesis, on the contrary, suggests that

environmental protection cannot be viewed as a hindrance to economic growth. Instead, appropriate environmental regulations can encourage firms to invest in R&D and innovation, thus reducing the costs of environmental governance while enhancing their core competitiveness. Green credit, as a financial instrument for environmental regulation, should follow a similar logic in its impact on enterprises. Specifically, GCP can either hinder GI by strengthening financing constraints or promote it by allocating resources and stimulating innovation through enterprises.

The GCP serves as both an environmental regulation and a resource allocation mechanism, making it a critical tool for investigating the connection between GCP and enterprise GI. This study explores the underlying principles of GCP in relation to enterprise GI from the perspective of resource allocation. The GCP serves as a tool for optimizing resource allocation, which is evident in various aspects. By following the implementation principle of the GCP, it influences investors' preferences and directs financial institutions to provide credit support to green environmental protection industries while excluding polluting enterprises. This approach ensures that funds are directed towards the environmental protection industry, thereby maximizing resource allocation within a set credit limit.

The implementation of the GCP facilitates commercial banks and other financial institutions in providing additional credit resources for green development enterprises that contribute to environmental protection. This, in turn, alleviates the financing constraints faced by these enterprises and encourages their investment in green R&D technology. The optimization of resource allocation can enhance enterprise innovation in several ways. Firstly, it can encourage enterprises to enter the green and environmental protection industry. With the availability of increased enterprise credit, high-efficiency and high-potential enterprises are more likely to invest in green projects. This enhances the impact of information channels and promotes GI (Xing et al., 2021). Secondly, it can stimulate existing enterprises to pursue GI. In the competitive market environment, commercial banks prioritize allocating resources to energy-saving and emission-reduction projects while strictly monitoring whether companies are engaged in green industry projects. This process ultimately leads to the elimination of high-polluting and high-emission projects, encouraging technological innovation among enterprises and promoting their green transformation and upgrading.

In summary, the GCP is a crucial instrument for environmental governance. It enhances support for green projects, regulates the credit scale of polluting enterprises, and drives the growth of the green economy. However, companies that prioritize cost-cutting may encounter challenges in implementing GI projects, including longer project durations, increased uncertainties, and greater risks, which could hinder their GI efforts. Additionally, technological spillover effects and high marginal costs relative to benefits may further reduce the incentive for enterprises to invest in GI. It is challenging for enterprises to meet the requirements and development needs of GI solely with their own resources, which can hinder GI despite the implementation of GCP. However, with the ongoing advancement of green finance, financial resources are increasingly being channeled towards green projects. Enterprises can enhance GI by capitalizing on the innovation compensation effect through collaborative patent applied with other companies or research institutions, integrating knowledge from diverse fields, and seizing opportunities to overcome technological innovation barriers. For this reason, we hypothesize that:

H1. *The GCP is not conducive to the independent GI of enterprises, but it is conducive to promoting enterprises to cooperate with other institutions to carry out GI.*

The theoretical framework for analyzing the impact of GCP on GI is shown in Figure 1.

The implementation of the GCP has prompted banking institutions to enhance their efforts in preventing environmental risks in credit operations. However, this has resulted in a reduction in credit investment in industries restricted by the GCP, leading to a decrease in bank credit and exacerbating enterprise credit constraints. Consequently, some enterprises are unable to obtain financial support from formal finance, hindering the development of GI activities (Hu et al., 2021). Under the alternative financing theory of commercial credit, enterprises experiencing significant pressure from severe "credit rationing" issues can turn to commercial credit as a means of mitigating the impact of GCP. Specifically, by delaying payments to upstream suppliers, enterprises can obtain commercial credit and alleviate their own credit fund shortage. Furthermore, the low entry threshold for commercial credit and greater financial support availability makes it possible for enterprises to leverage their own commercial credit financing as a crucial complement to green credit resources. This not only expands the pool of credit funds but also rationally adjusts capital structure, allowing enterprises to allocate more financial resources towards green R&D activities and promoting GI. For this reason, we hypothesize that:

H2. *Commercial credit has a moderating role in the process of GCP affecting GI of enterprises.*

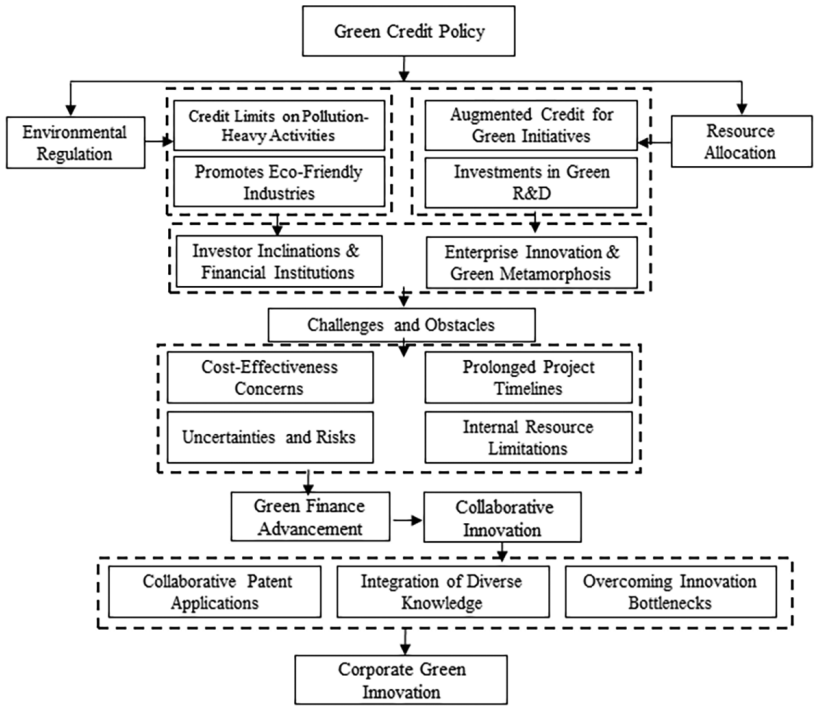

Figure 1. Impact of green credit policies on corporate green innovation

The GCP regulates the implementation of rules for commercial banks and other financial institutions. Specifically, the policy system, process, and supervision restrict banks from engaging in credit activities in industries restricted by the GCP. As a result, banks may reduce their debt financing in these industries, leading to increased corporate financing constraints. The impact of financing constraints on corporate GI can have both positive and negative effects. There are varying views among scholars regarding the relationship between financing constraints and enterprise GI. Some argue that firms with high financing constraints will naturally initiate GI, while others suggest that increased financial constraints can hinder such efforts (Khanna et al., 1998). The implementation of the GCP intensifies the difficulties faced by enterprises with high financing constraints in accessing funds for GI activities, thereby potentially hindering their ability to innovate sustainably. Furthermore, the uncertainty of innovation outcomes and the long lead time and high capital investment required for GI activities can make enterprises more vulnerable to financing difficulties. In this context, even if enterprises have a strong desire to increase their investment in innovation, they may be unable to carry out GI activities due to limited funds available, hindering their green transformation and upgrading efforts. For this reason, we hypothesize that:

H3. *The GCP will affect GI of enterprises through financing constraints.*

4. Research design

4.1. Sample selection and data sources

The study utilizes three primary data sources: financial data from publicly listed companies, green patent data from the same listed companies, and industry-level pollution data. Financial and green patent information was sourced from the China Research Data Service Platform (CNRDS), while the pollution data was extracted from the China Environmental Statistical Yearbook. This paper chooses Chinese enterprises in Shanghai and Shenzhen A-shares listed from 2006 to 2021 as the study sample. For the purpose of ensure data quality and research accuracy, the data processing in this article is as follows:(1) excluding companies in the financial and real estate industries; (2) excluding ST and PT listed companies; (3) excluding companies with significant missing data; and (4) excluding companies with gearing ratios less than 0 or greater than 1. To eliminate the impact of outliers, all control variables were subjected to 1% bilateral shrinkage. After matching the related variable data, a sample size of 9505 observations was granted. In order to address heteroskedasticity interference, some variables were logarithmically transformed in this study.

4.2. Identification strategy, model setting and variable selection

This study aimed to analyze the impact of GCP on enterprise GI and its underlying mechanism. Using the Guidelines issued in 2012 as a quasi-natural experiment, we employed continuous DID method to establish causality between the two variables. The treatment group was defined as those industries with GCP restrictions, while the control group consisted of non-GCP restrictive industries. We assigned a value of 1 to the year following 2012 (the year of promulgation of the Guidelines) and a value of 0 to years before that. By employing this

method, we were able to identify the causal relationship between the two variables and evaluate the effectiveness of GCP in promoting enterprise GI.

Most existing studies that employ the DID model to assess the effects of GCP define their treatment and control groups mainly at the industry level, such as high and low polluting enterprises, and whether they are subject to restrictions on GCP. However, this approach has some limitations. Firstly, industries may exhibit differences among themselves, and the impact of the policy may not be uniform across all industries. Secondly, estimating the extent to which enterprises are affected by the GCP solely based on differences between industries may not accurately identify the treatment group, leading to low credibility in the estimated results. To address these limitations, this paper proposes introducing a variable that describes the degree of influence of the GCP by multiplying it with the traditional DID term (*Treat*). We construct a cross-multiplier term to express the core explanatory variable (*gr_credit*) and use this to identify the average treatment effect of the GCP through the DID model. Based on our research hypotheses in the previous section, we present an econometric model in Eq. (1):

$$Gr_{it} = \alpha + \beta_1 gr\_credit_{jt} + \beta_2 Treat_{jt} + \lambda X_{it} + \mu_i + \nu_j + v_t + \gamma_{jt} + \varepsilon_{ijt}, \quad (1)$$

where, i represents the enterprise, j represents the industry, and t represents the year. The explained variables Gr_{it} represents the GI performance of enterprises i in year t; the core explanatory variables gr_credit_{jt} represents the degree to which the green credit-restricted industries are impacted by the GCP; $Treat_{jt}$ is the interaction term between the dummy variable before and after the promulgation of the Guidelines and whether the industry is a restricted industry by the GCP; X_{it} is a series of factors that affect the GI of enterprises; in order to exclude the influence of enterprise heterogeneity and industry shock on the empirical results, this paper controls the enterprise fixed effect μ_i, industry fixed effect ν_j, year effect v_t and industry × year fixed effect γ_{jt}; ε_{ijt} is the random disturbance term. If β_1 is significant and greater than 0, it means that with the increase in the intensity of GCP, the probability of enterprises to carry out GI changes, which means that GCP significantly promotes GI of enterprises.

4.2.1. Explained variable: enterprise GI

This study employs the number of green patents applied and granted as indicators of enterprise GI performance. With the national protection of the ecological environment, the number of green patents applied has been increasing, but the quality of patents is decreasing. Green patents can be divided into two categories: green invention patents and green utility model patents. However, considering that green utility models have low technical content and are significantly different from invention patents, this study uses the number of green invention patents as an indicator to measure GI. The numbers of green inventions independently applied for in a year (*gr_app*) and jointly applied for in a year (*gr_app_un*) represent the enterprise's green patent applied, while the numbers of green inventions independently granted in a year (*gr_gain*) and jointly granted in a year (*gr_gain_un*) represent the quality of their green patents. To address the right-skewed distribution of green patent data, this study adds 1 to the number of green patents before taking the natural logarithm. Additionally, to eliminate outliers, the data with green patents below the 1% quartile and above the 99% quartile is truncated.

4.2.2. Core explanatory variables: GCP

Expanding upon the traditional DID methodology (*Treat*), this paper introduces a novel variable termed "Pollution" to gauge the magnitude of impact stemming from GCP. The core explanatory variable indicator is constructed as the interaction term between the DID approach and the Pollution variable ($gr\_credit_{jt} = Treat_{jt} \times Pollution_{jt}$). To evaluate the impact of GCP on industries subject to restrictions, a standardized approach is employed. The "Pollution" variable employs a weighted average assessment of industrial emissions, encompassing the "three wastes" (industrial waste gas, wastewater, solid waste), along with industrial dust emissions at the industry level. The computation entails the creation of a composite pollution emission index, achieved by standardizing the emission levels of the four pollutants and aggregating them with uniform weights. This provides a comprehensive measurement of the overall pollution emissions situation at the industry level[2].

4.2.3. Control variables

Based on prior literature (Hu et al., 2021; Wang et al., 2022; Xing et al., 2021), this paper controls for a series of factors that may affect the GI of enterprises, including enterprise size (*Size*), return on assets (*ROA*), return on equity (*ROE*), net assets turnover ratio (*ATO*), cash flow ratio (*Cashflow*), the nature of the enterprise (*SOE*), growth rate of operating income (*Growth*), asset-liability ratio (*Leverage*).

4.3. Data description

Table 1 presents the descriptive statistics of the main variables used in this study. The mean values of the four explanatory variables are smaller than their standard deviations, indicating a significant difference between the green patent applied and granted among the sample

Table 1. Descriptive statistics of variables

Variables	Observations	Mean	Std. Dev.	Min	Max
gr_app	9505	0.2296	0.5464	0	2.0794
gr_gain	9505	0.1019	0.3234	0	1.3863
gr_app_un	9505	0.0739	0.2625	0	1.0986
gr_gain_un	9505	0.0333	0.1481	0	0.6931
gr_credit	9505	0.6035	0.3402	0	1
Size	9505	23.1067	1.3968	19.3048	25.9357
ROA	9505	0.0470	0.0594	–0.2466	0.2286
ROE	9505	0.0855	0.1206	–0.6993	0.3829
ATO	9505	0.6767	0.4669	0.0656	2.6489
Cashflow	9505	0.1120	0.1870	–0.7392	0.7149
SOE	9505	0.5564	0.4968	0	1
Growth	9505	0.1608	0.3465	–0.5796	2.4122
Leverage	9505	0.4831	0.1955	0.0569	0.8919

[2] Pollution data is sourced from the annual "China Environmental Statistical Yearbook" and "China Statistical Yearbook", and industry classification based on the "National Economic Industry Classification and Codes" is used to match the industries subject to restrictive GCP with the industries of the enterprises using two-digit industry codes.

enterprises. Additionally, the maximum value of the gearing ratio (*Leverage*) is 99%, highlighting the increasing debt pressure faced by enterprises and the need for them to adjust their capital structures vigorously.

5. Empirical analysis

5.1. Benchmark regression analysis

Table 2 presents the regression estimation results of Eq. (1). To enhance the reliability of these estimates, firm fixed effects, industry fixed effects, time fixed effects, and industry × year fixed effects have been included in all four models within this section. The results after adding all control variables indicate that the estimated coefficients of *gr_credit* in columns (1) and (2) are significantly negative at the 10% and 1% levels, respectively. This suggests that the GCP has a significant negative impact on both independent applied and granted of green patents. As the intensity of the GCP increases, enterprises affected by it experience a decrease in the number of independent applied and granted green invention patents, which amounts to 9.37% and 10.24%, respectively. This may be attributed to the fact that enterprises in industries with restrictive GCP face limitations due to the lack of access to additional credit funds. Furthermore, the Guidelines' strict control over environmental risks in the credit business has further intensified the financing constraints faced by enterprises under such policies, ultimately hindering their ability to engage in GI. Consequently, these GCP fail to achieve the desired Porter effect.

The regression coefficient of *gr_credit* in column (3) is significantly positive at the 1% statistical level, indicating that the GCP has a significant positive impact on the number of green inventions jointly filed by firms in that year. Specifically, it leads to an average increase in green inventions jointly filed by firms in that year by 9.41%. This may be attributed to the fact that, on the one hand, enterprises with a GI motivation are limited in their ability to invest in GI due to the constraints imposed by GCP. However, they can collaborate with other enterprises or scientific research institutions and draw on their scientific research capabilities and financial support to jointly undertake GI initiatives and apply for green patents. On the other hand, R&D funding, innovative talent, technology, experience, and management systems are significant factors affecting the GI of enterprises. Joint application can foster communication and cooperation among enterprises and enhance the technology spillover effect. Therefore, the GCP significantly promotes joint application of green patents by enterprises. The estimated coefficient of *gr_credit* in column (4) is negative and insignificant, indicating that the GCP does not have a significant impact on the number of green inventions jointly granted by firms in the year (*gr_gain_un*). This may be attributed to the fact that although the implementation of GCP can significantly enhance the number of green inventions jointly applied by enterprises, it fails to provide sufficient incentives for quality green patents. Additionally, the process of obtaining green patents takes 1–2 years, and the transformation cycle of green technological innovations is lengthy, requiring additional funds to mature the technology and gradually promote it. Furthermore, there is great uncertainty regarding the return on investment, which means that the GCP may discourage enterprises from joint applied for green inventions.

Table 2. Benchmark regression results

	gr_app	gr_gain	gr_app_un	gr_gain_un
	(1)	(2)	(3)	(4)
gr_credit	–0.0937*	–0.1024***	0.0941***	–0.0104
	(0.0480)	(0.0333)	(0.0294)	(0.0173)
Treat	–0.0656**	–0.0519***	0.0018	–0.0048
	(0.0263)	(0.0183)	(0.0161)	(0.0095)
Size	0.0634***	0.0369***	0.0254***	0.0085*
	(0.0122)	(0.0085)	(0.0075)	(0.0044)
ROA	–0.0525	–0.0660	–0.2033	–0.0317
	(0.2036)	(0.1414)	(0.1248)	(0.0735)
ROE	0.0494	0.0040	0.0994*	0.0324
	(0.0850)	(0.0590)	(0.0521)	(0.0307)
ATO	0.0228	0.0003	0.0253*	–0.0022
	(0.0214)	(0.0148)	(0.0131)	(0.0077)
Cashflow	–0.0268	–0.0092	–0.0003	0.0001
	(0.0274)	(0.0190)	(0.0168)	(0.0099)
SOE	0.0057	–0.0193	0.0194	–0.0079
	(0.0234)	(0.0163)	(0.0144)	(0.0085)
Growth	–0.0331***	–0.0125	–0.0073	–0.0068
	(0.0126)	(0.0088)	(0.0077)	(0.0046)
Leverage	–0.0813	–0.0258	0.0039	0.0096
	(0.0506)	(0.0351)	(0.0310)	(0.0182)
Constant	–1.1366***	–0.6481***	–0.5968***	–0.1555
	(0.2783)	(0.1932)	(0.1706)	(0.1004)
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes
N	9505	9505	9505	9505
R^2	0.6754	0.5532	0.4714	0.4246

Notes: the standard error value of robustness is in brackets; ***, ** and * are significant at the level of 1%, 5% and 10% respectively. The tables below are the same.

To summarize, hypothesis 1 has been confirmed. The implementation of GCP significantly reduces the number of green inventions independently applied for and granted by enterprises. The implementation of GCP significantly enhances the number of green inventions jointly applied for by enterprises, but it does not have a significant impact on the number of patents jointly granted for green inventions. It is evident that joint innovation by enterprises can continuously optimize their innovative technological resources and enhance their GI capabilities. GI requires the integration of resources from different fields, both inside and outside the enterprise, which makes it difficult for individual companies to meet the growing

demand for knowledge and improve their GI capabilities. With the current complex technology landscape and dispersed innovation elements, enterprises cannot solely rely on their own resources to meet the requirements and developmental needs of technological innovation. Therefore, it is crucial to find external partners to share resources and promote the enhancement of innovation capacity. In this regard, governments should implement policies that favor research investment and tax incentives to create a favorable innovation environment for enterprises. By doing so, they can encourage enterprises to collaborate with each other and work towards common goals, ultimately leading to more effective and sustainable GI.

5.2. Parallel trend test

The assumption that the treatment group and control group follow a parallel trend is one of the fundamental premises of the DID model. This means that prior to the implementation of the Guidelines, the growth rate of the GCP-restricted industries and non-GCP-restricted industries were similar, indicating the uniqueness of the policy period. In this study, we utilize the event analysis method to assess the disparity between the treatment and control groups before the policy's enactment, and construct a model as follows:

$$Gr_{it} = \beta_0 + \sum_{k=-6,k\neq-1}^{9} \beta_k gr\_credit_{jt}^{k} + \lambda X_{it} + \mu_i + \nu_j + v_t + \gamma_{jt} + \varepsilon_{ijt}. \quad (2)$$

Among them, k is the difference between each year and 2012, and $gr\_credit_{jt}^{k}$ is the implementation of the GCP in a specific year; If k is 0, it represents the dummy variable for the implementation of the GCP in 2012; if $k < 0$, it represents the first k years of the implementation of the policy; If $k > 0$, it means the last k years after the policy is implemented. The meaning of other variables is the same as formula (1). β_k is the coefficient concerned in study.

Figures 2 to 5 illustrate the effect of GCP on the four types of green patents owned by businesses. The figures present the results of a regression analysis conducted using Model (2), which reports the estimated coefficients and confidence intervals for *gr_credit*. Figure 2

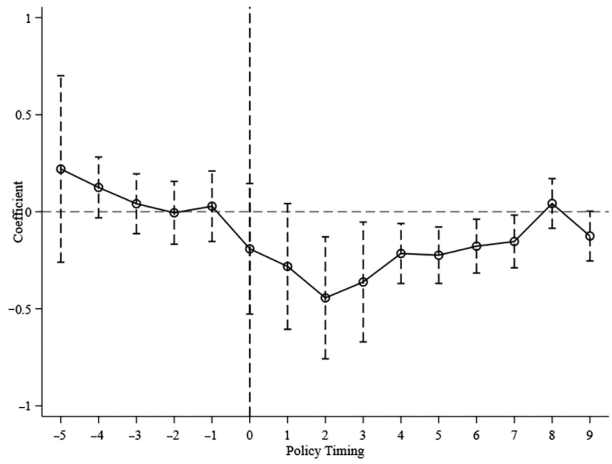

Figure 2. Parallel trend test of *gr_app*

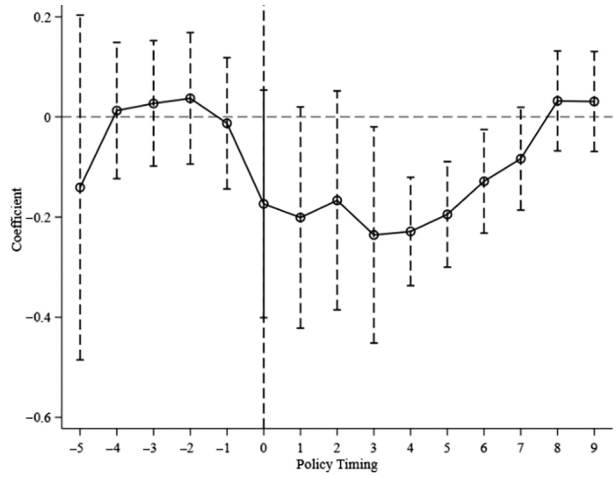

Figure 3. Parallel trend test of *gr_gain*

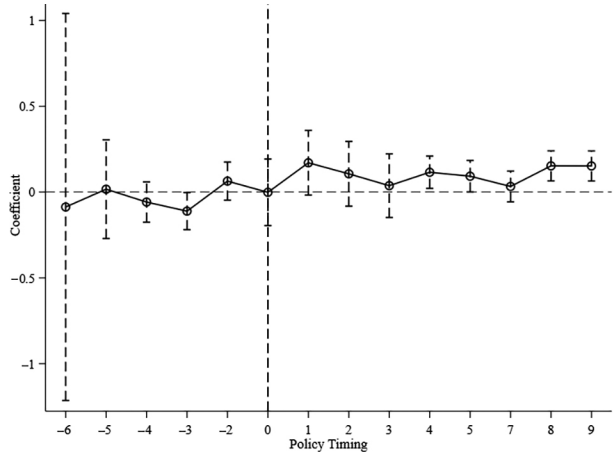

Figure 4. Parallel trend test of *gr_app_un*

displays a parallel trend test chart for *gr_app*, revealing a significant downward trend in the treatment group compared to the control group after 2011. The parallel trend test is passed. Figure 3 displays the results of the parallel trend test for *gr_gain*, which reveals that there was no significant difference between the treatment and control groups prior to the policy shock. The findings suggest that GCP has a significant impact on enterprises' independent granted of green invention patents in most years after 2011, with the inhibitory effect also passing the parallel trend test. Figure 4 illustrates that the treatment group experienced a notable increase in joint application of green invention patents, suggesting a positive effect of GCP. The estimated results prior to the base year were not significant, thus fulfilling the parallel trend assumption. Figure 5 presents the results of the parallel trend test, which reveals a notable decline in certain years following the base period. The parallel trend test is successfully passed.

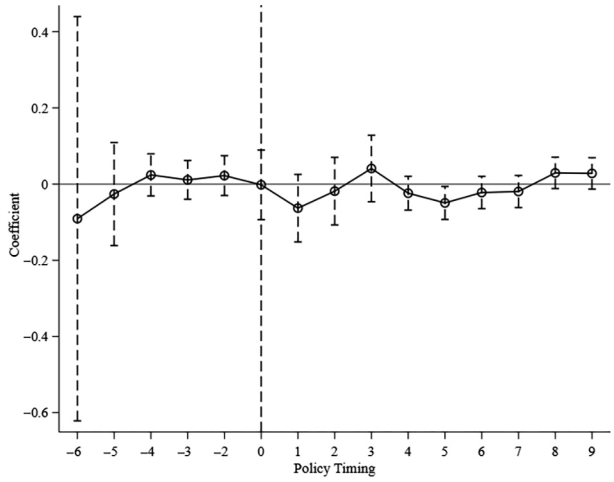

Figure 5. Parallel trend test of *gr_gain_un*

5.3. Robustness checks

5.3.1. Replace the explanatory variable measurement method

In this paper, the robustness test was conducted using alternative indicators of enterprise GI. The proportion of the number of green inventions to the sum of the total number of green inventions and green utility models were selected as the main indicators of enterprise GI. These alternative indicators were substituted as dependent variables into Equation (1) for regression analysis. The results are presented in Table 3. The estimated coefficients of *gr_credit* in columns (1)–(3) are shown to be significantly negative, negative, and positive at a 5%, 1%, and 1% statistical level respectively. This indicates that the implementation of GCP had a significant inhibitory effect on the number of green inventions independently applied for and granted by enterprises in that year, while promoting the number of green inventions jointly applied for by enterprises. The estimated coefficient of *gr_credit* in column (4) is negative but not statistically significant. The robustness test confirms that these benchmark regression results are robust.

5.3.2. Propensity score matching (PSM.DID)

In this study, the authors employed the propensity score matching (PSM) method to address potential sample selection bias. They selected control variables as covariates and estimated the propensity score using a logit model. Subsequently, they matched the control group with the closest score for matching purposes. By implementing 1:4 year-by-year neighbor matching with replacement, they ensured that there was no significant difference between the treatment and control groups before the Guidelines were issued, which helped to mitigate the endogenous interference of self-selection bias on the estimation results.

To enhance the reliability of the model matching results, we conducted a balancing test, and the results are presented in Table 4. They conducted a year-by-year PSM balance test and found that the standardized mean deviation (%bias) of the relevant control variables after matching was less than 5%. The p-values for the mean test between the matched

sample groups were all greater than 0.1, indicating that the null hypothesis of no significant difference between the treatment and control groups could not be rejected. Therefore, the balance test was passed.

Table 5 presents the findings of the PSM-DID regression. Due to the inability or difficulty to meet the common support assumption, propensity score matching (PSM) eliminates samples without a control group, which in turn reduces the sample size. Nevertheless, the estimated coefficients, signs, and significance levels of *gr_credit* are largely consistent with those of the benchmark regression results in Table 2, demonstrating that the results are robust.

5.3.3. Entropy balance matching method (EBM-DID)

In this paper, an additional approach called entropy balance matching is employed to bolster the validity of the research findings regarding the influence of GCP on enterprise GI (Chapman et al., 2019). Entropy balance matching is a method designed to minimize disparities between the treatment and control groups in each covariate by assigning a continuous weight to each observation in the control group. The objective is to achieve balance in each covariate by adjusting the distribution characteristics of the observed values. The results of entropy balance regression based on frequency weighting are presented in Table 6, which are consistent with those of the benchmark regression results in Table 2. This further reinforces the reliability of previous research findings.

Table 3. Replace the explained variable

	inv_app	*inv_gain*	*inv_app_un*	*inv_gain_un*
	(1)	(2)	(3)	(4)
gr_credit	–0.0673**	–0.0712***	0.0721***	–0.0265
	(0.0304)	(0.0262)	(0.0258)	(0.0215)
Treat	–0.0135	–0.0091	0.0044	0.0072
	(0.0167)	(0.0144)	(0.0141)	(0.0118)
Constant	–0.4503**	–0.1978	–0.3614**	–0.1590
	(0.1762)	(0.1518)	(0.1494)	(0.1243)
CVs	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes
N	9505	9505	9505	9505
R^2	0.5226	0.3799	0.3986	0.3506

Table 4. Year-by-year PSM balance test

	Size	*Lev*	*ROA*	*ROE*	*ATO*	*Cashflow*	*Growth*	*SOE*
%bias	1.0	2.7	–3.3	–3.4	–0.9	–3.4	–1.0	1.5
P value	0.699	0.303	0.220	0.161	0.753	0.184	0.702	0.579

Note: The table is the p-value of the mean test between matched sample groups after year-by-year matching.

Table 5. PSM-DID estimation results

	gr_app	*gr_gain*	*gr_app_un*	*gr_gain_un*
	(1)	(2)	(3)	(4)
gr_credit	–0.1211***	–0.1035***	0.0904***	–0.0105
	(0.0420)	(0.0290)	(0.0259)	(0.0154)
Treat	–0.0659**	–0.0510***	0.0072	0.0015
	(0.0275)	(0.0190)	(0.0170)	(0.0101)
Constant	–1.6993***	–0.9456***	–0.8320***	–0.1802
	(0.3452)	(0.2386)	(0.2132)	(0.1266)
CVs	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes
N	7345	7345	7345	7345
R^2	0.6774	0.5753	0.4926	0.4340

Table 6. EBM-DID estimation results

	gr_app	*gr_gain*	*gr_app_un*	*gr_gain_un*
	(1)	(2)	(3)	(4)
gr_credit	–0.1032***	–0.1093***	0.0967***	–0.0107
	(0.0372)	(0.0258)	(0.0232)	(0.0137)
Treat	–0.0789***	–0.0509***	0.0096	–0.0002
	(0.0248)	(0.0171)	(0.0154)	(0.0091)
Constant	–1.1569***	–0.8387***	–0.8754***	–0.1998*
	(0.2900)	(0.2007)	(0.1808)	(0.1066)
CVs	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes
N	9417	9417	9417	9417
R^2	0.6650	0.5537	0.4683	0.4198

5.3.4. Placebo test

5.3.4.1. Time placebo test

This paper conducts a counterfactual test by shifting the timing of the policy shock to 2009 (Cheng et al., 2021) and presenting the results in Table 7. The findings reveal that none of the estimated coefficients for *gr_credit2009* are significant, indicating that there is no substantial impact of the expected implementation of the GCP on enterprises' GI This confirms that the policy shock of the Guidelines has a significant impact on corporate GI, rather than other random factors.

Table 7. Time placebo test (Policy brought forward to 2009)

	gr_app	*gr_gain*	*gr_app_un*	*gr_gain_un*
	(1)	(2)	(3)	(4)
gr_credit2009	0.0029	–0.0384	0.0194	–0.0119
	(0.0777)	(0.0540)	(0.0476)	(0.0280)
Constant	–1.2319***	–0.7067***	–0.5643***	–0.1550
	(0.2829)	(0.1965)	(0.1735)	(0.1021)
CVs	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes
N	9417	9417	9417	9417
R^2	0.6735	0.5504	0.4683	0.4207

5.3.4.2. Randomly divide treatment and control groups

To further validate the robustness of our research conclusions, we conducted a placebo test through random grouping. Under the premise of keeping the time point of the GCP unchanged, the pseudo-treatment group was randomly selected from the sample. Regression analysis was performed to obtain the estimated coefficients of *gr_credit*, and kernel density distribution maps were generated based on 500 repeated random samplings. The purpose of this test was to rule out any possibility that the research conclusions were caused by accidental events or other unobservable factors. The results of the placebo test are presented in Figures 6, 7, and 8.

As illustrated in the figure, the mean values of the estimated coefficients in the random samples are substantially close to 0, which is a significant deviation from the actual regression coefficient estimates (–0.0937; –0.1024; 0.0941). The estimated coefficients exhibit a close-to-normal distribution, with most estimates having p-values greater than 0.1 and insignificant at the 10% statistical level. This suggests that the coefficient values are within the range of small probability events and that the true DID model estimation results are reliable and not influenced by stochastic factors.

5.3.5. Heckman sample selection model

Given the potential issue of selective bias in the sample, this paper used the Heckman selection model to further examine the impact of the implementation of GCP on enterprise GI. The Probit method was first used to estimate a dummy variable for whether the explained variable of the original regression equation was observed, and the inverse mills ratio (*IMR*) was then calculated. The *IMR* was used to correct possible sample selection bias in formula (1). The Heckman two-stage estimation results are presented in Table 8. The estimated coefficients, significance, and signs of *gr_credit* in columns (1)–(3) are similar to the benchmark regression results. After the implementation of GCP, the number of green inventions independently applied for and granted by enterprises decreased by 11.83% and 10.43% respectively, while

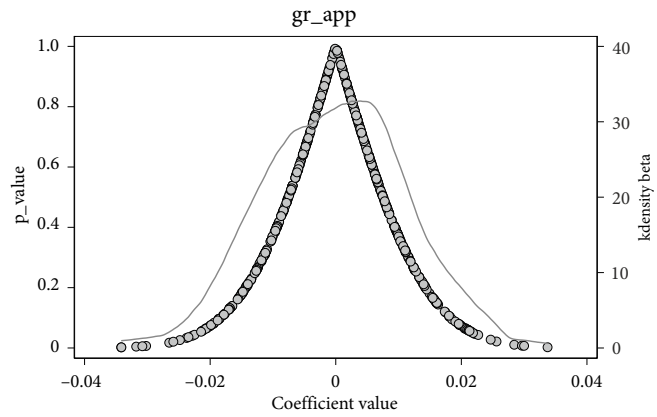

Figure 6. Placebo test of *gr_app*

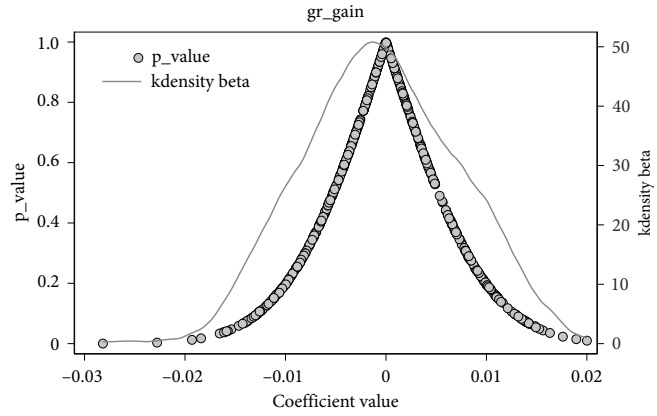

Figure 7. Placebo test of *gr_gain*

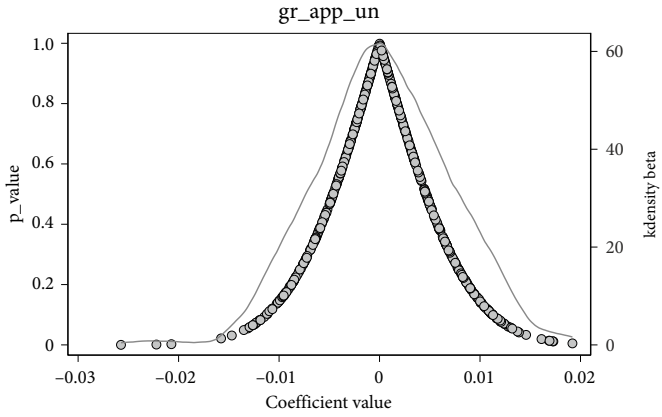

Figure 8. Placebo test of *gr_app_un*

the number of green inventions jointly applied for by enterprises increased by 16.69% on average. These results suggest that the use of the Heckman selection model helped to reduce self-selection bias and that the results are robust.

5.3.6. Exclude other policy influences

Since 2016, the State Council has approved "six provinces (regions) and nine places" to undertake the construction of green financial reform and innovation pilot zones. In terms of development trends, there are significant differences between green financial reform and innovation demonstration zones and other regions. To re-estimate the impact of GCP on corporate GI, this paper excludes the establishment of green financial reform and innovation pilot zones from the sample. The estimation results are shown in Table 9, which indicate that the estimation results excluding the influence of other policies are generally consistent with the benchmark regression results.

Table 8. Heckman two-stage estimation

	gr_app	*gr_gain*	*gr_app_un*	*gr_gain_un*
	(1)	(2)	(3)	(4)
gr_credit	–0.1183*	–0.1043**	0.1669***	0.0053
	(0.0678)	(0.0421)	(0.0448)	(0.0308)
Treat	–0.1203***	–0.0911***	–0.0189	–0.0092
	(0.0394)	(0.0231)	(0.0246)	(0.0169)
IMR1	2.9725			
	(1.8501)			
IMR2		1.2645		
		(1.0025)		
IMR3			2.8050***	
			(0.9727)	
IMR4				1.0533
				(0.7341)
Constant	–12.8024*	–6.3422	–11.7020***	–4.7862
	(7.1063)	(4.2315)	(3.7573)	(3.0986)
CVs	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes
N	9505	9505	9505	9505
R^2	0.8095	0.5965	0.5642	0.5430

Table 9. Exclude other policy influences

	gr_app	*gr_gain*	*gr_app_un*	*gr_gain_un*
	(1)	(2)	(3)	(4)
gr_credit	–0.1592***	–0.1063***	0.0951***	–0.0087
	(0.0553)	(0.0382)	(0.0336)	(0.0196)
Treat	–0.0922***	–0.0647***	0.0124	–0.0032
	(0.0301)	(0.0208)	(0.0183)	(0.0107)
Constant	–0.8616***	–0.7668***	–0.5542***	–0.0188
	(0.3238)	(0.2237)	(0.1965)	(0.1146)
CVs	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes
N	6936	6936	6936	6936
R^2	0.6703	0.5556	0.4854	0.4475

5.3.7. Control industry trends

This paper presents an approach to controlling factors that may impact enterprise GI by utilizing the industry trend effect. To this end, the paper adds enterprise fixed effect, industry fixed effect, year fixed effect, and industry-year trends to the regression equation. The results, shown in Table 10, indicate that the estimated coefficient, significance and sign of *gr_credit* are consistent with the benchmark regression results, suggesting that the research conclusions remain robust when controlling all industry trends.

Table 10. Control industry-year trends

	gr_app	*gr_gain*	*gr_app_un*	*gr_gain_un*
	(1)	(2)	(3)	(4)
gr_credit	–0.0862*	–0.1045***	0.0864***	–0.0128
	(0.0482)	(0.0335)	(0.0293)	(0.0172)
Treat	–0.0396*	–0.0348**	0.0013	0.0031
	(0.0236)	(0.0164)	(0.0143)	(0.0084)
Constant	–1.0799***	–0.5107***	–0.5404***	–0.1070
	(0.2761)	(0.1917)	(0.1675)	(0.0985)
CVs	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes
N	9505	9505	9505	9505
R^2	0.6573	0.5284	0.4532	0.4068

5.4. Heterogeneity analysis

5.4.1. Environmental regulation

The formulation and enforcement of environmental regulations can effectively tackle ecological and environmental issues. The Porter hypothesis posits that stringent yet reasonable environmental regulation intensity can motivate enterprises to undertake more GI activities, ultimately enabling them to innovate in an eco-friendly manner. The implementation of environmental regulations across different regions may vary in intensity. However, GCP plays a vital role as an effective tool for environmental regulation. The strict enforcement of environmental regulations can compel enterprises to invest in technological innovation and enhance the efficiency of their fund allocation (Porter, 1996). Moreover, the joint innovation of listed companies can compensate for the costs associated with environmental governance. Nevertheless, if environmental regulations are relaxed and firms' management takes opportunistic actions that do not adhere to environmental governance rules, the incentives for technological innovation will be diminished, thus shifting the risk to external parties.

Table 11 presents the estimated results of the impact of GCP on enterprise GI under different environmental regulation intensities. The results of the first four columns suggest that only the estimated coefficient of *gr_credit* in column (2) is significantly negative at the 5% statistical level, indicating that the implementation of GCP under weak environmental regulation significantly inhibits the number of enterprises that independently obtain green inventions. The results of the last four columns show that the GCP under strong environmental regulation significantly promotes the number of enterprises that jointly apply for green inventions. This suggests that under the intensity of strict environmental regulations, the management of listed companies will comprehensively examine the economic and environmental benefits of green R&D activities. Moreover, strict environmental regulation policies increase production costs, energy conservation and emission reduction costs, among others. Driven by the high costs, companies will unite and cooperate with other companies to carry out joint innovations. This joint strategy choice can realize technological innovation through resource sharing and reduce the cost of environmental governance.

5.4.2. Nature of enterprise ownership

In the current institutional context, there is an inevitable level of competition between state-owned enterprises and non-state-owned enterprises. Due to their higher credit ratings compared to non- state-owned enterprises, state-owned enterprises can more easily expand their financing channels and obtain bank loans. As the loans are often recoverable by banks, they are also willing to provide low-interest rates and less restrictive loan funds to state-owned enterprises. With financial support, state-owned enterprises are more motivated to increase their R&D investments and engage in GI activities. Following the implementation of GCP, there may be variations in the level of GI between state-owned and non-state-owned enterprises within GCP restricted industries. To address this issue, this paper divides the enterprises into two categories based on their nature of ownership, namely, state-owned and non-state-owned enterprises. Further, through regression analysis of grouped data, the paper examines the impact of ownership on the GI of enterprises with different natures of enterprise ownership. The findings are presented in Table 12. The study revealed that the number of in-

dependently applied and independently granted green inventions by state-owned enterprises were all negative at a 1% statistical level, while the number of jointly applied green inventions was significantly positive. However, it was not significant in the non-state-owned enterprise sample. This may indicate that the implementation of the GCP has a greater impact on state-owned enterprises with restrictive GCP, and to a certain extent confirms that they have higher credit status and are required to take on more policy-oriented tasks.

Table 11. Heterogeneity of environmental regulation intensity

	Weak environmental regulation				Strong environmental regulation			
	gr_app	*gr_gain*	*gr_app_un*	*gr_gain_un*	*gr_app*	*gr_gain*	*gr_app_un*	*gr_gain_un*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
gr_credit	0.0183	–0.1241**	0.0223	0.0148	–0.1073	–0.0356	0.1589***	–0.0095
	(0.0809)	(0.0583)	(0.0547)	(0.0305)	(0.0736)	(0.0497)	(0.0442)	(0.0268)
Treat	0.0520	–0.0341	0.0037	–0.0198	–0.1082**	–0.0577**	–0.0159	–0.0168
	(0.0498)	(0.0359)	(0.0336)	(0.0188)	(0.0432)	(0.0292)	(0.0260)	(0.0157)
Constant	–0.1360	–1.4147***	–0.7765**	–0.3441*	–1.6464***	–0.0527	–0.4661*	0.1843
	(0.5262)	(0.3795)	(0.3556)	(0.1987)	(0.4629)	(0.3126)	(0.2782)	(0.1686)
CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2993	2993	2993	2993	3155	3155	3155	3155
R^2	0.7303	0.6234	0.5021	0.4917	0.6705	0.5182	0.4654	0.4200

Table 12. Heterogeneity in the nature of enterprise ownership

	State-owned enterprise				Non-State-owned enterprise			
	gr_app	*gr_gain*	*gr_app_un*	*gr_gain_un*	*gr_app*	*gr_gain*	*gr_app_un*	*gr_gain_un*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
gr_credit	–0.2112***	–0.1951***	0.1018**	–0.0107	0.1190	0.0086	0.0367	–0.0171
	(0.0637)	(0.0453)	(0.0421)	(0.0242)	(0.0842)	(0.0564)	(0.0459)	(0.0288)
Treat	–0.0678**	–0.0635***	0.0178	–0.0130	–0.1414***	–0.0534	–0.0258	0.0194
	(0.0330)	(0.0234)	(0.0218)	(0.0125)	(0.0499)	(0.0335)	(0.0272)	(0.0171)
Constant	–1.0289***	–0.9332***	–0.6366**	–0.1389	–0.7633*	–0.3528	–0.2709	–0.0709
	(0.3972)	(0.2821)	(0.2622)	(0.1506)	(0.4472)	(0.2996)	(0.2437)	(0.1527)
CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	5251	5251	5251	5251	4120	4120	4120	4120
R^2	0.6968	0.5860	0.4980	0.4466	0.6717	0.5391	0.4559	0.4114

5.4.3. Executive education

The varying academic qualifications of executives play a crucial role in corporate governance. With intense competition and uncertainty, companies require non-replicable resources to achieve their strategic objectives. A diverse range of executive education can enhance the governance environment of a company, providing sustainable competitive resources and improving decision-making and management capabilities across the enterprise. Generally speaking, executives with a high educational background can exert a knowledge spillover effect and integrate different information resources through their specialized knowledge and skills, thereby enabling the implementation of the entire policy and reducing unnecessary time costs. In this paper, group regressions are conducted based on the division of executives' educational background into doctoral degree and non-doctoral degree, as shown in Table 13, which presents the estimation results of the heterogeneity of executives' educational background. Columns (1)–(4) are estimates for non-doctoral degree executive personnel, and the impact of GCP on the GI of firms with such executives is not substantial. This may be attributed to the fact that non-doctoral degree executives tend to have a more rigid mindset, which makes it difficult for them to adapt to dynamic and intricate markets, and consequently, reduces their decision-making efficiency. Columns (5)–(8) depict the estimation results for executives with doctoral degrees. The regression analysis revealed that the GCP has a more substantial impact on the GI of enterprises where the doctoral degree executives work. Moreover, these executives generally possess greater control and influence over the enterprise's overall decision-making processes. This implies that the higher the education level of an executive, the more beneficial it is to the corporate governance levels. Therefore, it is confirmed that executives with diverse educational backgrounds make a difference in the overall decision-making process of an enterprise's GI.

Table 13. Heterogeneity of executive education

	Executives with non-PhDs				Executives with PhDs			
	gr_app	*gr_gain*	*gr_app_un*	*gr_gain_un*	*gr_app*	*gr_gain*	*gr_app_un*	*gr_gain_un*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
gr_credit	–0.1080	–0.0384	–0.0146	–0.0190	–0.0957*	–0.1363***	0.1568***	0.0024
	(0.0918)	(0.0644)	(0.0523)	(0.0314)	(0.0575)	(0.0394)	(0.0367)	(0.0216)
Treat	–0.0837*	–0.0804**	0.0086	–0.0017	–0.0627**	–0.0342	0.0023	–0.0029
	(0.0494)	(0.0347)	(0.0282)	(0.0169)	(0.0317)	(0.0217)	(0.0202)	(0.0119)
Constant	–1.5454***	0.0727	–0.5674**	0.0342	–1.0000***	–1.0363***	–0.5636**	–0.2730**
	(0.5045)	(0.3539)	(0.2877)	(0.1724)	(0.3475)	(0.2381)	(0.2216)	(0.1302)
CVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	3617	3617	3617	3617	5762	5762	5762	5762
R^2	0.7028	0.5884	0.4818	0.4368	0.6620	0.5439	0.4849	0.4301

6. Further analysis

In this paper, we present Hypothesis 2 and Hypothesis 3, which suggest that GCP can exert an indirect influence on the GI of enterprises through its regulatory effect on commercial credit and its mediating role in financing constraints. To explore these mechanisms, we intend to conduct tests in two specific areas.

6.1. The moderating effect test of commercial credit

In order to verify Hypothesis 2, this paper constructs model (3) to empirically test the moderating effect of commercial credit financing on GCP. The specific expressions are as follows:

$$Gr_{it} = \alpha + \alpha_1 gr\_credit_{jt} + \alpha_2 CCF_{it} + \alpha_3 gr\_credit_{jt} \times CCF_{it} + \lambda X_{it} + \mu_i + \nu_j + \nu_t + \gamma_{jt} + \varepsilon_{ijt}, \quad (3)$$

where, CCF_{it} represents the scale of enterprise commercial credit financing. We use the comprehensive measurement of bills payable, accounts payable and accounts received in advance. Bills payable and accounts payable are deferred payment in order to alleviate the short-term capital gap, and accounts payable in advance are collected in advance to realize financing.

Table 14 presents the findings of the examination of the moderating effect of business credit on the GCP, with regression results indicating that the interaction term between the GCP and the scale of business credit financing significantly improves the number of independently granted green inventions and joint applied for green inventions by enterprises.

Table 14. Commercial credit moderating effect

	gr_app	*gr_gain*	*gr_app_un*	*gr_gain_un*
	(1)	(2)	(3)	(4)
gr_credit	–0.0994**	–0.1006***	0.0908***	–0.0165
	(0.0484)	(0.0334)	(0.0296)	(0.0174)
gr_credit×CCF	0.0190	0.0275*	0.0272**	0.0320***
	(0.0217)	(0.0150)	(0.0133)	(0.0078)
CCF	–0.0190	0.0809***	0.0248*	0.0055
	(0.0210)	(0.0145)	(0.0128)	(0.0076)
Treat	–0.0652**	–0.0479***	0.0040	–0.0030
	(0.0263)	(0.0182)	(0.0161)	(0.0095)
Constant	–1.1641***	–0.2924	–0.4463**	–0.0649
	(0.2840)	(0.1962)	(0.1739)	(0.1023)
CVs	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes
N	9505	9505	9505	9505
R^2	0.6755	0.5580	0.4729	0.4273

The moderating effect of the scale of commercial credit financing on the number of green inventions independently applied by enterprises is not statistically significant, suggesting that even though enterprises have access to commercial credit financing, it is challenging to allocate funds effectively and maximize resource value. The study also finds that the GCP has a not significantly negative effect on the number of green inventions jointly granted by enterprises. However, the moderating effect of the scale of commercial credit financing is economically significant for several reasons. Firstly, it takes some time for the GCP to improve the quality of GI among enterprises. Secondly, while commercial credit financing can help enterprises allocate resources towards research and development and promote green patent applied, the number of green patents granted is also not significantly negative. This indicates that even with the support of the policy, the short-term profit pursuit of enterprises may not be altered. Therefore, Hypothesis 2 was verified.

6.2. The mediation effect test of financing constraints

In order to test Hypothesis 3, that is, the GCP indirectly affects the GI of enterprises through the mechanism of financing constraint. This paper draws on the research of Baron and Kenny (1986) to construct a mediation effect model to test whether the financing constraint effect exists. The specific models are shown in Eqs (4) and (5):

$$SA_{it} = c + c_1 gr\_credit_{jt} + \lambda X_{it} + \mu_i + \nu_j + v_t + \gamma_{jt} + \varepsilon_{ijt}; \quad (4)$$

$$Gr_{it} = c + c_1' gr\_credit_{jt} + c_2' SA_{it} + \lambda X_{it} + \mu_i + \nu_j + v_t + \gamma_{jt} + \varepsilon_{ijt}, \quad (5)$$

where, the SA index represents financing constraints. In formula (4), if the coefficient c_1 is significant, it indicates that the GCP has a significant impact on the intermediary variable. In formula (5), if c_1' is significant and c_2' is not significant, it means that there is no mediation effect; if c_1' is not significant and c_2' is significant, it means that there is a complete mediation effect of financing constraints; if the coefficients c_1' and c_2' are both significant, it means that there is a partial mediation effect. If at least one of c_1 and c_2' fails the significance test, it needs to pass the bootstrap test.

This study uses two relatively exogenous variables, enterprise scale and business year, to construct financing constraints. Size represents the size of the enterprise, while Age is calculated as the observation year minus the establishment time of the enterprise. The SA indices are negative numbers that reflect the level of financing constraints faced by enterprises, with a larger absolute value indicating greater constraints (see Eq. (6)):

$$SA = -0.737 * \text{size} + 0.043 * \text{size}^2 - 0.040 * \text{Age}. \quad (6)$$

The results in Table 15, shown in column (1), indicate that the estimated coefficient of *gr_credit* for the impact of GCP on financing constraints is –0.0309, which is statistically significant at the 1% level. This suggests that GCP has a significant negative effect on enterprise financing constraints. However, when examining the results in column (2) for the number of enterprises independently applying for green inventions, we find that at least one coefficient fails the significance test. Consequently, a bootstrap test was conducted to obtain confidence intervals for the direct and indirect effects. The results revealed that the direct effect ranged

from [–0.0507, –0.0290] with a confidence interval, while the indirect effect ranged from [0.0332, 0.1011]. It is worth noting that the confidence interval of the bootstrap test did not include zero, indicating a significant mediation effect. Column (3) reveals that there is a partial mediation effect of the GCP on the number of green inventions independently granted by enterprises. Column (4) indicates that the GCP has a partial mediation effect on the joint application of green patents by enterprises, while column (5) shows that it has a complete mediation effect on the joint granted of green patents by enterprises.

The findings indicate that the implementation of the GCP has resulted in severe financing constraints for the restricted industries, making it more challenging for them to secure loans from banks. However, GI requires sufficient financial support. If the cost of financing is high for an enterprise, it may not be able to carry out its green projects normally due to a lack of funds, leading to a reduction in the number of green invention patents granted by the enterprise. Although the increase in the number of green inventions jointly applied for by enterprises, the number of independent applied and independently granted green inventions by enterprises, as well as the number of green inventions jointly granted by enterprises, have decreased. This suggests that industries restricted by the GCP have opted for strategic innovation, resulting in an increase in the number of green inventions being applied for but not necessarily an improvement in quality. In summary, the GCP indirectly impacts GI of enterprises through financial constraints, thus Hypothesis 3 is confirmed.

Table 15. Financing constraint effect

	(1)	(2)	(3)	(4)	(5)
	SA	*gr_app*	*gr_gain*	*gr_app_un*	*gr_gain_un*
gr_credit	–0.0309***	–0.0937*	–0.1019***	0.0945***	–0.0102
	(0.0115)	(0.0480)	(0.0333)	(0.0294)	(0.0173)
SA		0.0110	0.1193***	0.0830***	0.0507***
		(0.0381)	(0.0265)	(0.0234)	(0.0138)
Treat	0.0057	–0.0656**	–0.0520***	0.0018	–0.0048
	(0.0063)	(0.0263)	(0.0182)	(0.0161)	(0.0095)
Constant	–4.4030***	–1.0878***	–0.1216	–0.2307	0.0683
	(0.0667)	(0.3253)	(0.2255)	(0.1992)	(0.1173)
CVs	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes	Yes
N	9505	9505	9505	9505	9505
R^2	0.9427	0.6754	0.5543	0.4722	0.4256

7. Conclusions and policy implications

7.1. Research conclusion

This study employs the Guidelines as a quasi-natural experiment using data from Chinese A-share listed companies between 2006 and 2021, to construct a DID model and investigate the impact of the GCP on enterprise GI and its underlying mechanisms. The research findings are as follows: (1) The GCP has been found to significantly reduce the number of independently applied and granted green inventions by enterprises, while promoting the number of jointly applied green inventions. This suggests that the policy may not be conducive to independent GI but rather facilitates joint GI with other organizations. However, it is noteworthy that the impact of the GCP on the number of green inventions jointly granted by enterprises is not significant, indicating that the policy primarily improves quantity rather than quality in terms of joint enterprise strategies. (2) The results of this paper remain consistent after conducting robustness tests from various perspectives, including replacing the explanatory variable measures, using propensity score matching and entropy balance matching methods, placebo testing, estimation of Heckman selection model, excluding other policy effects, and controlling for industry trends. (3) The impact mechanism indicates that the influence of the GCP on corporate GI is moderated by business credit and mediated by financing constraints. (4) The impact of the GCP on the GI of enterprises is not uniform across different types of enterprises, as shown by the following observations: The number of joint applied for green inventions in regions with high environmental regulation intensity increased by an average of 15.89%, while the reduction in independently applied green inventions was relatively low. Additionally, the GCP impact on the GI of state-owned enterprises and those with a large number of PhD-educated executives was more significant. These findings suggest that promoting green transformation of enterprises is challenging under current circumstances and requires enhanced guidance and support.

7.2. Policy implications

Firstly, the paper highlights the importance of GCP in promoting GI and encourages enterprises to collaborate on GI practices. The theme of win-win cooperation is increasingly relevant in today's times, and joint innovation can lead to sustainable development and facilitate the transition towards a greener economy. Nevertheless, enterprise GI is a long-term endeavor, and while the number of enterprises jointly applying for green inventions has increased in the short term, further attention must be given to ensuring the quality of green invention patents by focusing on the granted of a sufficient number of them. The government should play a guiding role in promoting GI through the implementation of GCP. It is also necessary to strengthen information sharing mechanisms, encourage joint efforts among enterprises, and direct green credit funds towards research and development activities to enhance the quality of GI.

Second, it is imperative to further implement GCP and introduce differentiated incentive schemes to offer support. The government should expedite the development of a financial system, ensuring that enterprises with different characteristics have access to credit funding

support. This will encourage them to participate in GI activities. On the one hand, the current GCP should be enforced and enhanced to efficiently allocate enterprise resources and direct funds towards green projects. On the other hand, differentiated incentive policy support should be vigorously implemented to offer preferential support to enterprises engaged in green projects and achieving GIs. This will encourage enterprises to collaborate and innovate together, thereby improving the "quality" and "quantity" of their green invention patents.

Third, emphasize the importance of business credit and establish a long-term mechanism for green projects to achieve a genuine transformation from "light green" to "deep green". On one hand, under the GCP, it is important for enterprises to strengthen their relationships with regional businesses and collaborate by creating regional cooperative networks and business alliances in agglomerations. This will effectively guarantee a stable supply of commercial credit. By making reasonable use of commercial credit, enterprises can broaden their financing channels, alleviate the challenge of insufficient credit funds, and ensure that there are sufficient funds for their GI activities. On the other hand, in implementing the GCP, the government should give due consideration to its role in resource allocation. It can invest financial resources in green environmental protection projects and mobilize the enthusiasm of enterprises to participate in such initiatives.

Moreover, the government can refine the industry classification for enterprises and prohibit commercial banks from imposing credit thresholds. It is crucial to pay attention to the "green washing" phenomenon among enterprises engaged in joint GI, with a view to ensuring that they truly transition from "light green" to "deep green". The relevant government departments can consider promoting exchanges and cooperation among enterprises, enhancing green credit incentive policies, and leveraging the main functions of enterprises rather than resorting to strategic innovations to alleviate financing constraints.

8. Limitations and future research directions

The current study has some limitations that suggest areas for future research. Firstly, it only focuses on the impact of the GCP on enterprise GI in China, and the findings may not be generalizable to other countries or regions. Secondly, the study considers the number and quality of green inventions as the outcome variable, and further research can explore the impact of GCP on the commercialization of GIs. Thirdly, the study only examines the short-term impact of GCP on enterprise GI, and future research can explore the long-term impact of the policy.

In light of these limitations, future research plans should focus on addressing these gaps. Firstly, the study can be extended to investigate the impact of other environmental policies and regulations on enterprise GI, and to compare the effectiveness of different policy tools. Secondly, the study can explore the impact of GCP on the innovation performance and competitiveness of enterprises. Thirdly, the study can examine the role of different stakeholders, such as governments, financial institutions, and NGOs, in promoting GI and sustainable development. Fourthly, the study can investigate the impact of the GCP on the innovation behavior and performance of different types of enterprises, such as small and medium-sized enterprises and multinational corporations.

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Data availability

Data and code are available upon request.

Conflict of interests

The authors have no relevant financial or non-financial interests to disclose.

References

Abakah, E. J. A., Nasreen, S., Tiwari, A. K., & Lee, C. C. (2023). US leveraged loan and debt markets: Implications for optimal portfolio and hedging. *International Review of Financial Analysis*, *87*, Article 102514. https://doi.org/10.1016/j.irfa.2023.102514

Acemoglu, D., Akcigit, U., Hanley, D., & Kerr, W. (2016). Transition to clean technology. *Journal of Political Economy*, *124*(1), 52–104. https://doi.org/10.1086/684511

Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R., & Van Reenen, J. (2016). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. *Journal of Political Economy*, *124*(1), 1–51. https://doi.org/10.1086/684581

An, S., Li, B., Song, D., & Chen, X. (2021). Green credit financing versus trade credit financing in a supply chain with carbon emission limits. *European Journal of Operational Research*, *292*(1), 125–142. https://doi.org/10.1016/j.ejor.2020.10.025

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*(6), 1173–1182. https://doi.org/10.1037/0022-3514.51.6.1173

Chapman, K., Miller, G. S., & White, H. D. (2019). Investor relations and information assimilation. *The Accounting Review*, *94*(2), 105–131. https://doi.org/10.2308/accr-52200

Cheng, F., Wang, C., Chiao, C., Yao, S., & Fang, Z. (2021). Retail attention, retail trades, and stock price crash risk. *Emerging Markets Review*, *49*, Article 100821. https://doi.org/10.1016/j.ememar.2021.100821

Cui, X., Wang, P., Sensoy, A., Nguyen, D. K., & Pan, Y. (2022). Green credit policy and corporate productivity: Evidence from a quasi-natural experiment in China. *Technological Forecasting and Social Change*, *177*, Article 121516. https://doi.org/10.1016/j.techfore.2022.121516

Fan, H., Peng, Y., Wang, H., & Xu, Z. (2021). Greening through finance? *Journal of Development Economics*, *152*, Article 102683. https://doi.org/10.1016/j.jdeveco.2021.102683

Francis, J., & Smith, A. (1995). Agency costs and innovation some empirical evidence. *Journal of Accounting and Economics*, *19*(2–3), 383–409. https://doi.org/10.1016/0165-4101(94)00389-M

Gao, W., & Liu, Z. (2023). Green credit and corporate ESG performance: Evidence from China. *Finance Research Letters*, *55*(B), Article 103940. https://doi.org/10.1016/j.frl.2023.103940

He, L., Liu, R., Zhong, Z., Wang, D., & Xia, Y. (2019a). Can green financial development promote renewable energy investment efficiency? A consideration of bank credit. *Renewable Energy*, *143*, 974–984. https://doi.org/10.1016/j.renene.2019.05.059

He, L., Zhang, L., Zhong, Z., Wang, D., & Wang, F. (2019b). Green credit, renewable energy investment and green economy development: Empirical analysis based on 150 listed companies of China. *Journal of Cleaner Production*, *208*, 363–372. https://doi.org/10.1016/j.jclepro.2018.10.119

Houston, J. F., & Shan, H. (2022). Corporate ESG profiles and banking relationships. *The Review of Financial Studies*, *35*(7), 3373–3417. https://doi.org/10.1093/rfs/hhab125

Hu, G., Wang, X., & Wang, Y. (2021). Can the green credit policy stimulate green innovation in heavily polluting enterprises? Evidence from a quasi-natural experiment in China. *Energy Economics*, *98*, Article 105134. https://doi.org/10.1016/j.eneco.2021.105134

Khanna, M., Quimio, W. R. H., & Bojilova, D. (1998). Toxics release information: A policy tool for environmental protection. *Journal of Environmental Economics and Management*, *36*(3), 243–266. https://doi.org/10.1006/jeem.1998.1048

Lee, C. C., & Lee, C. C. (2022). How does green finance affect green total factor productivity? Evidence from China. *Energy Economics*, *107*, Article 105863. https://doi.org/10.1016/j.eneco.2022.105863

Lee, C. C., Chang, Y. F., & Wang, E. Z. (2022b). Crossing the rivers by feeling the stones: The effect of China's green credit policy on manufacturing firms' carbon emission intensity. *Energy Economics*, *116*, Article 106413. https://doi.org/10.1016/j.eneco.2022.106413

Lee, C. C., Qin, S., & Li, Y. (2022a). Does industrial robot application promote green technology innovation in the manufacturing industry? *Technological Forecasting and Social Change*, *183*, Article 121893. https://doi.org/10.1016/j.techfore.2022.121893

Lee, C. C., Wang, F., & Chang, Y. F. (2023a). Does green finance promote renewable energy? Evidence from China. *Resources Policy*, *82*, Article 103439. https://doi.org/10.1016/j.resourpol.2023.103439

Lee, C. C., Wang, F., & Chang, Y. F. (2023b). Towards net-zero emissions: Can green bond policy promote green innovation and green space? *Energy Economics*, *121*, Article 106675. https://doi.org/10.1016/j.eneco.2023.106675

Liu, X., Wang, E., & Cai, D. (2019). Green credit policy, property rights and debt financing: Quasi-natural experimental evidence from China. *Finance Research Letters*, *29*, 129–135. https://doi.org/10.1016/j.frl.2019.03.014

Lu, Y., Gao, Y., Zhang, Y., & Wang, J. (2022). Can the green finance policy force the green transformation of high-polluting enterprises? A quasi-natural experiment based on "Green Credit Guidelines". *Energy Economics*, *114*, Article 106265. https://doi.org/10.1016/j.eneco.2022.106265

Luo, S., Yu, S., & Zhou, G. (2021). Does green credit improve the core competence of commercial banks? Based on quasi-natural experiments in China. *Energy Economics*, *100*, Article 105335. https://doi.org/10.1016/j.eneco.2021.105335

Lv, C., Fan, J., & Lee, C. C. (2023). Can green credit policies improve corporate green production efficiency? *Journal of Cleaner Production*, *397*, Article 136573. https://doi.org/10.1016/j.jclepro.2023.136573

Nabeeh, N. A., Abdel-Basset, M., & Soliman, G. (2021). A model for evaluating green credit rating and its impact on sustainability performance. *Journal of Cleaner Production*, *280*, Article124299. https://doi.org/10.1016/j.jclepro.2020.124299

Porter, M. (1996). America's green strategy. *Business and the Environment: A Reader*, *33*.

Reghezza, A., Altunbas, Y., Marques-Ibanez, D., d'Acri, C. R., & Spaggiari, M. (2022). Do banks fuel climate change? *Journal of Financial Stability*, *62*, Article 101049. https://doi.org/10.1016/j.jfs.2022.101049

Scholtens, B., & Dam, L. (2007). Banking on the Equator. Are banks that adopted the Equator Principles different from non-adopters? *World Development*, *35*(8), 1307–1328. https://doi.org/10.1016/j.worlddev.2006.10.013

Stucki, T., Woerter, M., Arvanitis, S., Peneder, M., & Rammer, C. (2018). How different policy instruments affect green product innovation: A differentiated perspective. *Energy Policy*, *114*, 245–261. https://doi.org/10.1016/j.enpol.2017.11.049

Su, C. W., Li, W., Umar, M., & Lobont, O. R. (2022a). Can green credit reduce the emissions of pollutants? *Economic Analysis and Policy*, *74*, 205–219. https://doi.org/10.1016/j.eap.2022.01.016

Su, C. W., Umar, M., & Gao, R. (2022b). Save the environment, get financing! How China is protecting the environment with green credit policies? *Journal of Environmental Management*, *323*, Article 116178. https://doi.org/10.1016/j.jenvman.2022.116178

Sun, C., & Zeng, Y. (2023). Does the green credit policy affect the carbon emissions of heavily polluting enterprises? *Energy Policy*, *180*, Article 113679. https://doi.org/10.1016/j.enpol.2023.113679

Sun, H., Edziah, B. K., Kporsu, A. K., Sarkodie, S. A., & Taghizadeh-Hesary, F. (2021). Energy efficiency: The role of technological innovation and knowledge spillover. *Technological Forecasting and Social Change*, *167*, Article 120659. https://doi.org/10.1016/j.techfore.2021.120659

Taghizadeh-Hesary, F., & Yoshino, N. (2019). The way to induce private participation in green finance and investment. *Finance Research Letters*, *31*, 98–103. https://doi.org/10.1016/j.frl.2019.04.016

Tan, X., Xiao, Z., Liu, Y., Taghizadeh-Hesary, F., Wang, B., & Dong, H. (2022a). The effect of green credit policy on energy efficiency: Evidence from China. *Technological Forecasting and Social Change*, *183*, Article 121924. https://doi.org/10.1016/j.techfore.2022.121924

Tan, X., Yan, Y., & Dong, Y. (2022b). Peer effect in green credit induced green innovation: An empirical study from China's Green Credit Guidelines. *Resources Policy*, *76*, Article 102619. https://doi.org/10.1016/j.resourpol.2022.102619

Tiwari, A. K., Abakah, E. J. A., Adewuyi, A. O., & Lee, C. C. (2022). Quantile risk spillovers between energy and agricultural commodity markets: Evidence from pre and during COVID-19 outbreak. *Energy Economics*, *113*, Article 106235. https://doi.org/10.1016/j.eneco.2022.106235

Tombe, T., & Winter, J. (2015). Environmental policy and misallocation: The productivity effect of intensity standards. *Journal of Environmental Economics and Management*, *72*, 137–163. https://doi.org/10.1016/j.jeem.2015.06.002

Wang, C. W., Lee, C. C., & Wu, L. T. (2023). The relationship between cash flow uncertainty and extreme risk: International evidence. *Pacific-Basin Finance Journal*, *77*, Article 101927. https://doi.org/10.1016/j.pacfin.2022.101927

Wang, H., Qi, S., Zhou, C., Zhou, J., & Huang, X. (2022). Green credit policy, government behavior and green innovation quality of enterprises. *Journal of Cleaner Production*, *331*, Article 129834. https://doi.org/10.1016/j.jclepro.2021.129834

Wang, Y., Lei, X., Long, R., & Zhao, J. (2020). Green credit, financial constraint, and capital investment: Evidence from China's energy-intensive enterprises. *Environmental Management*, *66*(6), 1059–1071. https://doi.org/10.1007/s00267-020-01346-w

Wang, Z., & Wang, X. (2022). Research on the impact of green finance on energy efficiency in different regions of China based on the DEA-Tobit model. *Resources Policy*, *77*, Article 102695. https://doi.org/10.1016/j.resourpol.2022.102695

Wen, H., Lee, C. C., & Zhou, F. (2021). Green credit policy, credit allocation efficiency and upgrade of energy-intensive enterprises. *Energy Economics*, *94*, Article 105099. https://doi.org/10.1016/j.eneco.2021.105099

Xing, C., Zhang, Y., & Tripe, D. (2021). Green credit policy and corporate access to bank loans in China: The role of environmental disclosure and green innovation. *International Review of Financial Analysis*, *77*, Article 101838. https://doi.org/10.1016/j.irfa.2021.101838

Xu, X., & Li, J. (2020). Asymmetric impacts of the policy and development of green credit on the debt financing cost and maturity of different types of enterprises in China. *Journal of Cleaner Production*, *264*, Article 121574. https://doi.org/10.1016/j.jclepro.2020.121574

Yao, S., Pan, Y., Sensoy, A., Uddin, G. S., & Cheng, F. (2021). Green credit policy and firm performance: What we learn from China. *Energy Economics*, *101*, Article 105415. https://doi.org/10.1016/j.eneco.2021.105415

Yin, W., Zhu, Z., Kirkulak-Uludag, B., & Zhu, Y. (2021). The determinants of green credit and its impact on the performance of Chinese banks. *Journal of Cleaner Production*, *286*, Article 124991. https://doi.org/10.1016/j.jclepro.2020.124991

Zhang, A., Deng, R., & Wu, Y. (2022a). Does the green credit policy reduce the carbon emission intensity of heavily polluting industries? Evidence from China's industrial sectors. *Journal of Environmental Management*, *311*, Article 114815. https://doi.org/10.1016/j.jenvman.2022.114815

Zhang, K., Li, Y., Qi, Y., & Shao, S. (2021b). Can green credit policy improve environmental quality? Evidence from China. *Journal of Environmental Management*, *298*, Article 113445. https://doi.org/10.1016/j.jenvman.2021.113445

Zhang, S., Wu, Z., He, Y., & Hao, Y. (2022b). How does the green credit policy affect the technological innovation of enterprises? Evidence from China. *Energy Economics*, *113*, Article 106236. https://doi.org/10.1016/j.eneco.2022.106236

Zhang, S., Wu, Z., Wang, Y., & Hao, Y. (2021a). Fostering green development with green finance: An empirical study on the environmental effect of green credit policy in China. *Journal of Environmental Management*, *296*, Article 113159. https://doi.org/10.1016/j.jenvman.2021.113159

Zhou, F., Wen, H., & Lee, C. C. (2022). Broadband infrastructure and export growth. *Telecommunications Policy*, *46*(5), Article 102347. https://doi.org/10.1016/j.telpol.2022.102347