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Green Credit Policy, Institution Supply and Enterprise Green Innovation

Chunji Zheng [a, b], Feng Deng [a, b], Chengfeng Zhuo [c, *], Weiheng Sun [d]

[a] *School of Economics and Management, Xinjiang University, Urumqi, China*
[b] *Center for Innovation Management Research in Xinjiang, Xinjiang University, Urumqi, China*
[c] *Institute of Guangdong, Hong Kong and Macao Development Studies, Sun Yat-sen University, Guangzhou, China*
[d] *Business School, Imperial College London, London, UK*

ABSTRACT

Green credit policy (GCP) relies on financial means to promote environmental governance. Whether it can achieve the goals of economic development and environmental protection, especially in the context of different institutional supplies, remains to be scientifically tested. Based on the implementation of China's Green Credit Guidelines in 2012, this study uses panel data of Chinese companies from 2009 to 2019 to explore the influence of GCP on green technology innovation and the role of institutional supply in it. The results show that GCP is instrumental in promoting green innovation in heavily polluting enterprises, and the promotion effect is heterogeneous based on green patent types, firms' ownership, and regional financial development levels. Further analysis finds that the supply of environmental protection systems by local governments can strengthen the green innovation effect of GCP. However, the institutional supply of innovation has not yet released a promotional effect. This paper finds that green credit can be used as an environmental governance tool and provides inspiration for local governments to issue environmental protection policies scientifically.

KEYWORDS

Green credit policy; Government system supply; Enterprise green innovation; Difference in Difference model; Regulatory mechanism

* Corresponding author: Chengfeng Zhuo
E-mail address: zhuochf@mail.sysu.edu.cn

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1. Introduction

Global environmental remediation is urgently needed (Feng et al., 2018; Zhu et al., 2019). However, in developing countries, especially in China (Wang et al., 2021), sacrificing the environment for short-term economic gain is often the preferred option. Since 2010, China's rising pollutant emissions have further deteriorated air quality (Hao et al., 2020). Existing studies suggest that green innovation, i.e., technological innovation that promotes green development and improves environmental quality, is essential to enhancing the green competitiveness of enterprises (Magat, 1978; Hart, 1995; Dechezleprêtre et al., 2019). Therefore, promoting green technological innovation and energizing green innovation of enterprises are essential paths to green development. However, green innovation has characteristics of strong externality, high investment, and primary risks. Without external policy intervention, enterprises that aim to maximize profits are often reluctant to engage in green innovation. Therefore, it is essential to study and address how to better drive the green innovation of enterprises.

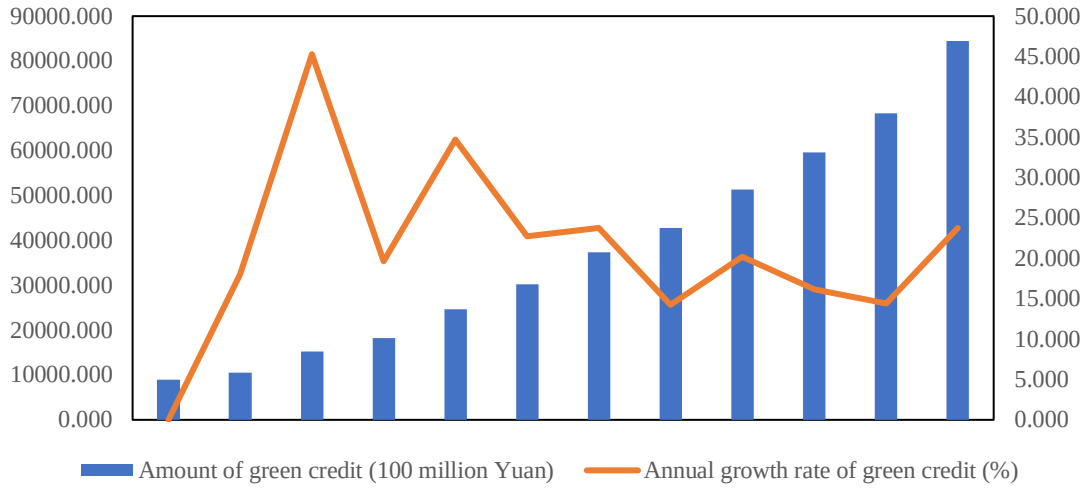

Figure 1. Green credit balance and annual growth rate from 2009 to 2020.

With the promotion of government environmental regulation and the continuous expansion of the development of green finance, green credit policy (GCP) has become a key strategy to regulate the deployment of enterprise credit resources. Specifically, financial institutes provide financing support and favorable policies to relevant enterprises and institutions engaged in the green economy and correspondingly adjust and restrict the loan interest rate, loan amount, loan type, and examination and approval procedures of non-green enterprises to achieve the purpose of enterprise transformation and environmental protection. As shown in Fig. 1, China's green credit balance has been growing steadily since 2009 and exceeded CNY 8 trillion in 2020, an increase of 23.76 percent compared with the previous year. Its unique loan constraints and strict credit rationing system provide a driving force for realizing the green transformation of enterprises. Additionally, the GCP affects internal capital investment, technological innovation decision-making, and resource reallocation among enterprises by setting up a dual restraint mechanism of environmental access threshold and credit quota control. However, information asymmetry and different institutional environments exist in policy practice. Green credit often faces problems such as moral hazard and credit mismatch in the implementation process, affecting the implementation of GCP and producing unexpected results (Shen et al., 2014). Therefore, what kind of impact will GCP have on green innovation? In particular, regional governments in China tend to pursue local economic development goals by relaxing local environmental regulations. Thus, under the institutional arrangements for environmental protection provided by local governments, will the green innovation effect of GCP change? Additionally, what impact will the internal and external environmental differences faced by enterprises bring to GFP? This paper responds to the above questions.

The possible marginal creations are as follows: First, focusing on heavily polluting enterprises, this paper expands the research on green innovation and conducts empirical tests on the effect of financial means on green development. Second, it introduces China's unique local government system into the analysis framework and examines how the local government's institutional supply affects green credit enforcement and enterprise green innovation to provide a theoretical foundation for administration to improve system supply and fully release the GCP effect. Third, considering the differences of enterprises in innovation behavior, ownership, and external financing environment, the heterogeneity of GCP is investigated, providing decision-making references for the scientific and accurate formulation and implementation of GCP.

2. Literature review

In the performed works, the influence of environmental regulation (ER) on green innovation has been widely studied. The "Inhibition theory" and the "Promotion theory" are two mainstream conclusions. Researchers who support the "inhibition theory" believe that ER increases the expenditure for environmental management and system compliance of enterprises (Clarkson et al., 2004). Faced with high-intensity ER, enterprises have to take measures such as purchasing corresponding pollution control equipment or reducing production and shutting down to meet environmental standards. This may cause enterprises to lack sufficient funds for R&D and innovation, inhibiting green technology innovation (Dean, 2000; Greenstone et al., 2012; Petroni et al., 2019), which is the "follow cost" effect. "Promotion theory" advocates that ER implementation can force enterprises to control pollution costs and strengthen their core competitiveness. Enterprises may reduce the amount of pollution discharge through green technology research and development (Guellec et al., 2003; Chakraborty et al., 2017; Cui et al., 2018), resulting in the effect of "innovation compensation." Bu et al. (2020) used ISO14000 environmental certification as an instrumental variable for environmental regulation and found that voluntary ISO14000 environmental certification is beneficial to improving innovation output.

As a type of environmental policy, GCP effects are explored. First, some literature examined changes in financial institutions' performance after GCP promulgation. GCP effectively restrains the rise of non-performing loan ratio, helps to improve its reputation, and effectively promotes risk management. Therefore, the bank is profitable (Cilliers et al., 2011; Williams, 2013; Biswas, 2016). Opposing views suggest that green credit has the characteristics of long-term, prime rate, and cumbersome review, which may have a negative impact on the bank performance (Scholtens et al., 2007; Mathuva et al., 2016). Therefore, financial institutions may lack sufficient motivation to implement GCP (Biswa, 2011). The second is to explore the strategic response of enterprises to GCP. Since the introduction of GCP, non-clean enterprises have faced the pressure of shortened debt maturity and high environmental pollution costs. They may have to reduce production scale or carry out industrial transformation (Zhu et al., 2017; Liu et al., 2019). Meanwhile, enterprises engaged in green production may have ample resources for green technology innovation (Li et al., 2018; He et al., 2019). However, due to corporate inaction and insufficient implementation of GCP, the policy effect is gradually weakening (Zhang et al., 2011; Omnimasivaya et al., 2016).

It is worth noting that due to institutional heterogeneity, in the absence of environmental supervision and insufficient protection of intellectual property rights, many chaotic phenomena, such as government-enterprise collusion to soften supervision and copycat instead of innovation, may occur. These issues have become a serious constraint that hinders GCP from encouraging enterprise green innovation. Optimizing credit resource distribution is a material way for GCP to influence the green innovation of enterprises (Goetz, 2019; He et al., 2019). The environmental protection policy and innovation policy motivate enterprises to make innovation decisions (García et al., 2017; Jin et al., 2019), and then adjust the resource allocation mechanism of GCP (Wang et al., 2021). However, for the research on GCP impact, government institution supply is rarely noticed in the performed works.

By reviewing the relevant literature, this paper finds that there has been relatively rich research on the impact

of GCP on enterprise green innovation. However, there are still three areas that need further expansion. Firstly, the existing literature mainly focuses on the financial performance of policy implementers and the strategic behavior of micro enterprises when discussing the implementation effect of GCP. However, there is relatively little literature on whether GCP will affect the green innovation of heavily polluting enterprises. Secondly, existing works about the creation effect of GCP have ignored the guiding role of government institution supply. In fact, the effectiveness of GCP needs the support of environmental protection policies issued by the government and relevant laws and regulations. Finally, the existing literature has ignored the heterogeneous effect of GCP on green innovation, which may lead to a deviation in the policy effect of GCP. Therefore, from the perspective of government institution supply, this paper aims to study the promotion effect of green innovation on the implementation of GCP by comprehensively considering various heterogeneous categories, including innovation behavior, enterprise nature, and regional financial development.

3. Theoretical analysis

3.1. Effect path of GCP on enterprise green innovation

In 2012, China promulgated a document named the Green Credit Guidelines, which stipulated the implementation standards of green credit in detail from the aspects of organization and management, system construction, information disclosure, supervision, inspection, etc. The GCP mainly includes three important measures. First, banks are asked to implement differentiated and dynamic credit policies for enterprises in the field of green production and enterprises with major environmental risks, industrial policies, and industry access policies. Secondly, it refines the list of a compliance review of enterprises by banking regulators and improves the specific process and key time points of dynamic review of loan qualification. Thirdly, it further strengthens the internal control management and information disclosure provisions. It requires the banking industry to strengthen the supervision of the implementation of GCP, and it also requires the banking industry to establish a performance evaluation and incentive system for green credit business. The specific influencing mechanism is analyzed as follows:

(1) Financing constraint effect. Different from environmental policy tools such as mandatory emission reduction and environmental tax, GCP mainly internalizes the environmental cost of enterprises through financing channels. In terms of credit availability and loan financing cost, GCP makes heavily polluting enterprises reduce their financing channels and increase credit difficulty. Financing constraints will force enterprises to make transformations through green technology innovation (Su et al., 2018).

(2) Signal release effect. The implementation of GCP requires the participation of multiple stakeholders, such as enterprises, financial institutions, and government departments, and it is pivotal for the external evaluation of enterprises. On the one hand, the GCP can release the signal that the state will support clean industries inflow into the capital market and can help investors directly choose green environmental protection enterprises to make investment, thus avoiding the problem of information asymmetry. For heavily polluting enterprises facing the negative signal that financial institutions restrict credit to heavily polluting enterprises, under the pressure of survival, they have to rely on green technology innovation to solve the development dilemma caused by GCP. On the other hand, the GCP requires banks to increase information disclosure, so the enterprise environmental information will be transmitted through the bank, which alleviates the problem of information asymmetry between the government and enterprises. This enables the government to more effectively supervise the production process of green environmental protection and heavily polluting enterprises and encourages enterprises to improve green production technology and efficiency under the requirements of environmental performance (Wang et al., 2021).

(3) Risk dispersion effect. Previous studies have shown that in regions where the intensity of environmental regulation fluctuates greatly, the innovation compensation effect is inhibited (Xie et al., 2016). The fluctuating

environmental policies aggravate the risk of change in the choice of technological innovation direction, and it is difficult for firms to make an optimal choice under the condition of changing the choice domain of technological innovation direction, thus showing a strong wait-and-see psychology. The Green Credit Guidelines require banking financial institutions to specify the assessment criteria for environmental information in corporate loan approval and specify the areas of credit support. This further clarifies the enterprise's innovation direction and the environmental standards of technology. Accordingly, we propose Hypothesis 1: The GCP can promote green innovation of heavily polluting enterprises.

3.2. Regulating the effect of government institution supply

Although GCP has a normative program, the implementation effect of the policy is closely related to the completeness of relevant supporting institutions. The government has also played an important role in promoting enterprises' green innovation through mandatory institutional supply.

The effectiveness of GCP needs the support of environmental protection policies and relevant laws and regulations, which means that strengthening the environmental protection system can effectively improve the resource allocation efficiency of green credit. Governmental environmental protection institution supply can significantly improve environmental protection law enforcement, prompting local heavily polluting enterprises to reduce pollution emissions and increase green innovation (Shen et al., 2017). The improvement of environmental protection law enforcement weakens the government's ability to intervene in the allocation of credit resources and increases the pressure on banks' supervision costs and reputation damage caused by loans to heavily polluting enterprises. Therefore, the resource-induced utility of GCP may be more obvious. In areas with a poor supply of environmental protection systems, the law enforcement environment and strength are weak. In order to pursue GDP growth, local governments may intervene in the distribution of credit funds, resulting in differences in the implementation effect of GCP, and the policy's implementation effect may not be obvious. Therefore, Hypothesis 2 is proposed: The supply of environmental protection institutions can strengthen the promotion effect of GCP on green innovation of heavily polluting enterprises.

The role of innovation institutions in green innovation has two sides. First, as an important institutional arrangement for enterprises, innovation institution supply can crack down on infringement behaviors, such as copycats and counterfeiting, reducing the external risks of enterprises to carry out innovation activities. Second, too strict IPR protection can strengthen the monopoly power of intellectual property owners, reduce free competition, and profit incentives for R&D, which is adverse to innovation (O'donoghue et al., 2004; Lorenczik et al., 2012; Liu et al., 2018). In addition, the high profits brought by property right monopoly can alleviate financing constraints for firms, and then the enterprise's innovation power decreases. Accordingly, Hypothesis 3 is proposed: Innovation institution supply may weaken the promotion effect of GCP on green innovation of heavily polluting enterprises.

4. Data and methods

4.1. Sample selection

Taking all A-share listed companies from 2009 to 2019 as the research object, we eliminated the following samples: companies in the financial insurance industry, companies with an asset-liability ratio less than 0 or greater than 1, companies with abnormal transactions (including ST, * ST, and PT), and listed companies without available data. The data sources for this paper mainly consist of three parts: (1) patent data obtained from CNIPA. (2) Characteristic data of other companies mainly collected from the CSMAR database. (3) Regional data collected from the China Statistical Yearbook and the Peking University Law Database (PKULAW.CN) over the years.

4.2. Model building

The implementation of GCP is not a random event. If the ordinary least square method is used for estimation, it may cause selective deviation of estimation results. Therefore, based on Green Credit Guidelines, the Difference in Difference (DID) model is adopted to test the promotion effect of GCP on green innovation. The model settings are as follows:

$$Innov_{it} = \beta_0 + \beta_1 Treat_i \times Post_t + \gamma X_{it-1} + \delta_i + \eta_j + \lambda_t + \varepsilon_{it} \quad (1)$$

Among them, $Innov_{it}$ represents the green innovation performance of listed company i in year t. $Treat_i$ represents the dummy variable of GCP implementation. According to the types of environmental and social risks specified by the former China Banking Regulatory Commission in Key Evaluation Indicators for the Implementation of Green Credit, this paper determines whether the listed company is in an industry restricted by green credit according to whether the enterprise belongs to the listed "environmental and social risk of class A". If yes, $Treat_i = 1$. Otherwise, it was identified as the control group, $Treat_i = 0$.For $Post_t$, the value of the post-implementation period (2012 and later) is 1, and the value of the pre-implementation period (before 2012) is 0. The interaction term $Treat_i \times Post_t$ is a DID variable. X_{it-1} represents a series of control variables. δ_i represents enterprise fixed effect. η_j and λ_t represent region and time fixed effect and ε_{it} random error term.

Further, the variable *Institu* of government system supply is introduced on the basis of Model (1) to test the regulatory effect of government system supply on the green innovation promotion effect of GCP. The model construction form is as follows:

$$Innov_{it} = \beta_0 + \beta_1 Treat_i \times Post_t + \beta_2 Treat_i \times Post_t \times Institu_{it} + \gamma X_{it-1} + \delta_i + \eta_j + \lambda_t + \varepsilon_{it} \quad (2)$$

Among them, β_2 reflects the difference between restricted enterprises and non-restricted enterprises by green credit.

4.3. Variable measure

4.3.1. Enterprise green innovation

The research perspective is to examine the effectiveness of GCP through the green technology innovation activities of listed companies. Therefore, we measure the green innovation (*Innov*) of listed companies by the number of green patent applications.

4.3.2. Enterprise green innovation

How to objectively quantify the system has been a long-term concern in academia. There are no official authoritative statistics on the micro data of the promulgation and implementation of environmental and innovative policies. PyCharm software is used to write a web crawler program in order to quantify the supply level of environmental protection institutions and innovation institutions.

Environmental protection institution (*EPS*). Based on the Peking University law database (PKULAW.CN), we obtained local regulations, government regulations, authority files, and local working files related to pollution control in all provinces, cities, and autonomous regions of China in 2009-2019. The timeliness of the document is "current and effective", and the search keyword is "environmental pollution". For innovation institution supply (*IPS*), the search keyword is "intellectual property rights". The supply level of EPS and IPS in each province/city/autonomous region is described by the logarithm of the number of environmental protection documents per 10,000 people.

4.3.3. Control variables

This paper selects the influencing factors of enterprise economic characteristics as the control variables. Enterprise scale ($Size$) is measured by the logarithm of the total capital at the end of the year. Generally speaking, large-scale enterprises will make relatively stable R&D investment (Bu et al., 2020). Corporate liabilities (Lev), represented by the ratio of the loan amount to total assets to measure the liabilities of enterprises. Moderate debt can create a financial leverage effect, and increase innovative investment (Meuleman et al., 2012). Company value (TQ). $TobinQ$ value reflects its ability to create social value. In this paper, it is processed by logarithm. In addition, this paper controls both enterprise age (Age) and ownership concentration (Cen). Among them, Age is measured by the logarithm of listing time; Cen is denoted by the proportion of the largest shareholder.

5. Empirical results and analyses

5.1. Baseline result analysis

In Table 1, we estimate the benchmark model without control variables (columns (1)-(3)) and the model including control variables (columns (4)-(6)). In columns (1)-(3), the coefficient of the DID term is significantly positive. After controlling for enterprise, time, and region fixed effects, the coefficient decreases significantly. After further adding control variables, the coefficient of the DID term remains positive in columns (4)-(6). This indicates that GCP has significantly promoted green innovation. With respect to the control variables, enterprise scale has a significantly positive impact on green innovation. Corporate debt has a negative impact. This is because when enterprises bear a high debt, managers often choose low-risk and high-profit projects for investment, whereas green technology R&D requires a lot of funding, a long R&D cycle, and is uncertain, which weakens managers' willingness to invest in green innovation R&D. The coefficients of other control variables are not significant, indicating that they have no significant effect on enterprises' green technology innovation.

Table 1. Estimated Results of the Impact of GCP on Enterprise Green Innovation.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
$Treat$	27.079***	5.078**	5.055**	21.773***	4.687**	4.628**
$\times Post$	(7.835)	(1.817)	(1.820)	(7.031)	(1.855)	(1.858)
$Size$				4.509***	1.296***	1.338***
				(0.659)	(0.277)	(0.280)
Lev				-9.240***	-2.652*	-2.636*
				(1.932)	(1.458)	(1.468)
Cen				0.011	0.014	0.015
				(0.024)	(0.019)	(0.020)
Age				-3.354***	0.638	0.625
				(0.458)	(1.327)	(1.332)
TQ				1.088***	-0.002	-0.004
				(0.186)	(0.148)	(0.149)
$Cons$	2.128***	2.723***	2.724***	-88.825***	-27.391***	-28.351***
	(0.182)	(0.161)	(0.161)	(13.890)	(7.001)	(7.077)
Enterprise	NO	YES	YES	NO	YES	YES
Time	NO	YES	YES	NO	YES	YES
Region	NO	NO	YES	NO	NO	YES
R^2	0.0277	0.7010	0.7002	0.0704	0.7012	0.7005
N	8888	8888	8885	8682	8682	8679

*Note: *, * * and * * * indicate significance levels of 10%, 5% and 1%, respectively. Standard deviations are in parentheses.*

5.2. Sample selection

This paper conducts robustness tests from multiple dimensions, such as parallel trend tests, changing industry definition standards, replacing explanatory variables, and introducing missing variables.

5.2.1. Parallel trend test

The parallel trend hypothesis is a key assumption of the DID method (Abadie, 2005), which requires parallel trend tests on the outcome variables of the treatment group and the control group. Therefore, this paper advanced the implementation time of GCP by one or two years uniformly to verify whether the parallel trend hypothesis is satisfied. As shown in Column (1) of Table 2, the coefficients of F1.DID and F2.DID did not pass the significance test, indicating that there was no significant difference in green innovation between the treatment group and the control group before the implementation of GCP.

5.2.2. Parallel trend test

In addition to Class A, construction, production, and business activities of Class B will also produce adverse environmental and social consequences. The difference between Class A and Class B is that this problem can be easily eliminated through mitigation measures for Class B, and Class B customers with insufficient risk release measures will still be included in the list of major environmental and social risks. Therefore, according to the industries of Class B enterprises, we expand the identification scope of industries restricted by green credit. If the listed companies belong to the above 25 industries, we also recognize them as industries restricted by green credit. Column (2) in Table 2 reports the results after redefining the industry type. $Treat \times Post$ is instrumental for green patents. This also confirms the reliability of the benchmark regression results.

5.2.3. Considering the high risk of innovation

Table 2. Robustness test.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
F1.*DID*	3.484 (2.139)					
F2.*DID*	4.423 (2.870)					
$Treat$		2.915**	19.207***	29.021***	10.363***	4.619**
$\times Post$		(1.382)	(1.876)	(2.097)	(1.363)	(1.871)
$Size$	1.311***	1.356***	1.828***	2.749***	1.492***	1.352***
	(0.281)	(0.280)	(0.283)	(0.317)	(0.218)	(0.284)
Lev	-2.891**	-2.803*	-3.909***	-6.914***	-4.393***	-2.702*
	(1.468)	(1.469)	(1.482)	(1.657)	(1.182)	(1.488)
Cen	0.014 (0.020)	0.015 (0.020)	0.027 (0.020)	0.024 (0.023)	0.011 (0.016)	0.015 (0.020)
Age	0.723 (1.332)	0.618 (1.332)	0.332 (1.345)	1.808 (1.504)	1.817* (1.056)	0.554 (1.349)
TQ	-0.008	-0.005	0.173 (0.150)	0.415**	0.065 (0.116)	-0.004
	(0.149)	(0.149)		(0.168)		(0.150)
Hum						9.913* (5.944)
$Cons$	-28.162***(7.073)	-28.684*** (7.075)	-39.186*** (7.146)	-63.055***(7.989)	-33.875***(5.451)	-53.233*** (16.468)
Enterprise	YES	YES	YES	YES	YES	YES
Time	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES
City						YES
R^2	0.701	0.7004	0.6948	0.6188	0.8548	0.7001
N	8679	8679	8679	8679	6324	8594

It usually takes a long time for major and substantial innovations that can bring technological progress and product upgrade to succeed. Referring to the practice of He et al. (2013), we select the green patent applications in t + 1 and t + 2 years to measure green innovation. In Table 2, specific regression results are shown in columns (3)-(4). It can be seen that after considering the long periodicity of the green innovation process, we find that the impact of the interaction term $Treat \times Post$ on green patents is significantly positive, which is still robust.

5.2.4. Considering the statistical standard

The statistical standard of the patent application was changed in 2017, and the regression was carried out again after excluding the samples in 2017 and later. In Column (5) of Table 2, the coefficient of $Treat \times Post$ is positive, which proves the robustness of the benchmark regression result again.

5.2.5. Considering missing variables

There may be missing variables. To address this issue, the variable of the human capital level of the city where the enterprise is registered is introduced into Model (1). High-quality talents are a key factor for enterprises to innovate. The higher the human capital level of a city, the more conducive it is to exert the promotion effect of GCP on enterprises' green innovation. In addition, it also controls the city fixed effect. In Table 2, Column (6) reports the corresponding results. The coefficient sign and significance of the cross-multiplication term have not changed after the introduction of the missing variable. Therefore, the basic conclusion that GCP can significantly promote enterprise green innovation is reliable.

5.3. Regulation of system supply

Table 3. Regression results of the regulatory effect of institution supply.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
$EPS \times Treat \times Post$	2.383 (1.716)	2.305 (1.745)			4.911** (2.022)	4.934** (2.056)
$IPS \times Treat \times Post$			-1.996(1.569)	-2.172 (1.607)	-4.371** (1.849)	-4.577** (1.893)
$Treat \times Post$	-5.987 (5.987)	-6.046 (8.290)	13.273**(6.713)	13.535** (6.848)	0.297 (8.578)	0.549 (8.725)
$Size$		1.337*** (0.280)		1.347*** (0.280)		1.355*** (0.280)
Lev		-2.641* (1.468)		-2.619* (1.468)		-2.610* (1.468)
Cen		0.015 (0.020)		0.015 (0.020)		0.015 (0.020)
Age		0.608 (1.332)		0.628 (1.332)		0.596 (1.332)
TQ		-0.001 (0.149)		-0.004 (0.149)		0.002 (0.149)
$Cons$	2.724*** (0.161)	-28.281***(7.077)	2.724*** (0.161)	-28.569***(7.079)	2.724*** (0.161)	-28.659*** (7.077)
Enterprise	YES	YES	YES	YES	YES	YES
Time	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES
R^2	0.7002	0.7005	0.7002	0.7005	0.7004	0.7007
N	8885	8679	8885	8679	8885	8679

The impact of GCP on green innovation is not an independent event, which often needs the support of

government institution supply. After discussing the net effect of GCP on green innovation, the regulatory effect of government institution supply on green innovation is further investigated. The interaction terms of environmental protection institution, innovation institution, and GCP are added to the benchmark model, respectively.

Table 3 reports the estimated results. Columns (1) and (2) report the regression results of the regulation mechanism of the supply of environmental protection institution. The coefficient of $EPS \times Treat \times Post$ is positive and fails to pass the significance test. Columns (3) and (4) report the regression results of the regulation mechanism of the supply of innovation institution. The coefficient of $IPS \times Treat \times Post$ is negative and fails to pass the significance test. Columns (5) and (6) report the regression results of the regulation mechanism under the joint action of environmental protection institution supply and innovation institution supply. The coefficient of $EPS \times Treat \times Post$ is significantly positive, indicating that the institution supply of government environmental protection can significantly enhance the promotion effect of GCP on green innovation of heavily polluting enterprises. The coefficient of $IPS \times Treat \times Post$ is significantly negative, which means that the government innovation institution supply has significantly weakened the promotion effect of GCP on green innovation of heavily polluting enterprises. At the same time, the positive effect of environmental protection institution supply is greater than the negative effect brought by innovation institution supply. The above results show that only under the joint action of environmental protection institution and innovation institution, the government institution supply can significantly adjust the promotion effect of GCP on green innovation. This is because environmental protection institution and intellectual property institution are an organic unity, and the two are inseparable. Faced with environmental problems such as resource shortage and fragile environment, the government institution supply of environmental protection has "forced" non-clean enterprises to promote their green innovation output by increasing pollution control costs. Because the innovation achievements have strong externality and are easy to be imitated, free riding occurs frequently. At this time, the supply of government innovation institution is particularly important. However, the innovation institution supply not only strengthens the monopoly power of intellectual property owners, but also exacerbates the financing constraints of heavily polluting enterprises due to the high profits brought by property monopoly, and then inhibits the effect of GCP on stimulating green innovation.

5.4. Heterogeneity analysis

In view of the potential differences in the impact of GCP on enterprise innovation due to enterprise heterogeneity and regional heterogeneity, this study examines the differential impact of GCP on enterprise green innovation based on the characteristics of multi-dimensional heterogeneity.

5.4.1. Heterogeneity of green patent types

Green patents include two types: green invention (GI) and green utility (GU) models. The former requires formal and substantive review and has a strict review process, high application costs, long average review cycles, and low success rates. Therefore, firms tend to favor GU model patents. The more severe financing constraints faced by enterprises due to GCP imply that the green innovation activities of firms may exhibit strategic behavior by only pursuing the quantity of innovation and ignoring the improvement of quality (Tong et al., 2014; Hall et al., 2012).

In Table 4, Column (1) shows the estimated results of the impact of GCP on GI. The coefficient of the interaction term is positive, indicating that GCP can significantly increase GI. Meanwhile, the coefficient in Column (2) is consistent, indicating that the implementation of GCP is also conducive to GU. However, the promotion effect of GCP on GI is greater than that of GU. This means that the implementation of GCP substantially increases the innovation competitiveness of enterprises mainly by promoting GI, instead of GU. Firms engage in real innovation to achieve green development, rather than simply seeking policy support through strategic behavior.

5.4.2. Heterogeneity of enterprise ownership

China's state-owned and private enterprises have long been significantly different in their ability to obtain loans from banks. For banks, the probability of debt default for state-owned enterprises is small because of the implicit guarantee of the government. In addition, state-owned enterprises tend to survive for a long time, and the information asymmetry is relatively weak, so they face fewer financing constraints than private enterprises (Brandt et al., 2003). There is also credit discrimination in the implementation of GCP. Therefore, based on the benchmark model, the overall sample is divided into state-owned enterprises and private enterprises to further investigate whether the GCP will produce heterogeneous effects for different types of enterprise subjects.

Table 4 Heterogeneity test results of the impact of GCP on enterprise green innovation.

Variable	GI	GU	State-owned enterprise	Private enterprises	High level of financial development	Low level of financial development
	(1)	(2)	(3)	(4)	(5)	(6)
$Treat$	2.683*	1.945***	4.917*	-0.2613	7.499***	-0.705
$\times Post$	(1.522)	(0.538)	(2.640)	(2.109)	(2.754)	(1.343)
$Size$	0.981***	0.358***	2.062**	0.357*	1.759***	0.522**
	(0.229)	(0.081)	(0.472)	(0.200)	(0.416)	(0.211)
Lev	-2.013*	-0.623	-3.644	-1.932**	-4.094*	-0.014
	(1.203)	(0.425)	(2.573)	(0.983)	(2.163)	(1.143)
Cen	0.015	0.0003	0.031	-0.012	0.031	-0.017
	(0.016)	(0.006)	(0.034)	(0.014)	(0.029)	(0.015)
Age	0.738	-0.113	0.861 (2.639)	1.088 (0.841)	1.476	-0.948
	(1.091)	(0.386)			(1.930)	(1.062)
TQ	-0.026	0.021	-0.076	-0.007	-0.029	0.042
	(0.122)	(0.043)	(0.325)	(0.085)	(0.213)	(0.123)
$Cons$	-21.641***	-	-	-8.069*	-39.519***	-7.353
	(5.798)	6.709***(2.049)	44.876***(12.951)	(4.856)	(10.472)	(5.372)
Enterprise	YES	YES	YES	YES	YES	YES
Time	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES
R^2	0.6974	0.5878	0.7113	0.3884	5715	2765
N	8679	8679	5064	3594	0.7071	0.2884

In Table 4, the coefficient of the $Treat \times Post$ is significantly positive in Column (3), which is non-significant in Column (4). The green technology innovation effect of GCP on heavily polluting enterprises does have heterogeneity at the attribute level of enterprise ownership. For state-owned enterprises, the GCP effect is obvious; for private enterprises, the GCP inhibits the green technology innovation effect of heavily polluting enterprises, but it is not significant. The possible reason is that state-owned enterprises need to fulfill the social objectives of the government in environmental protection and green and high-quality development. GCP releases a market signal that the state will support the development of green and clean industries, which will further stimulate the state-owned enterprises to strengthen green innovation activities in response to the call of the country. For private heavily polluting enterprises, they often face credit discrimination. More serious financing constraints occurred after GCP, resulting in a situation of "willing spirit but weak flesh" in green innovation. Driven by interests, it will weaken the enterprise's green innovation motivation and occupy green R&D investment, which is adverse to their green technology innovation.

5.4.3. Heterogeneity of financial development level

The degree of regional financial development can expand or limit enterprises' financing sources and choices (Rajan et al., 1998). In areas with a high level of financial development, financial institutions can obtain more comprehensive information about borrowing enterprises and effectively evaluate the quality of green innovation projects, thereby reducing investment risks caused by information asymmetry. In areas with a low level of financial development, the serious problem of information asymmetry increases the cost of approval and supervision of financial institutions. Obtaining external financing at a lower price is difficult, which creates financing constraints on the green innovation activities of enterprises and affects the promotion effect of GCP on green innovation. Credit markets are divided into groups at different development levels (Hsu et al., 2014), and regions are divided into high and low financial development levels based on the third percentile of the loan balance of the city where the listed enterprise is registered in GDP, to further study the heterogeneous impacts of GCP.

In Table 4, the coefficient of the interaction term is positive in Column (5), and negative in Column (6). GCP can significantly promote green technology innovation in regions with a high level of financial development. For regions with a low level of financial development, the effect of GCP on green technology innovation is limited, but not significant. When conducting green credit business in areas with a high level of financial development, banks can invest more human capital to review the qualifications of heavily polluting enterprises that need to borrow and supervise policy implementation, and the effect of GCP in promoting green innovation of enterprises is fully realized. When the level of financial development is low, GCP not only increases enterprises' financing costs, but also limits their financing channels, which is adverse to green innovation.

6. Conclusion and enlightenment

Green technology innovation is the fundamental support and key driving force for realizing green and low-carbon economic development. In this study, we investigated the impact of GCP on the green innovation of heavily polluting enterprises and the role of institution supply, and the results are as follows:

(1) GCP plays a significant role in promoting the green innovation of heavily polluting enterprises. To further improve the GCP system, credit institutions should continue to develop green finance and innovate financial products. Additionally, supervisory measures should be strengthened to increase the proportion of liquidity, pricing, risk, and other indicators related to green credit in supervision and assessment, thus improving the positive incentive mechanism and risk prevention mechanism of green credit.

(2) To build an efficient and complementary institution supply system, we need to fully utilize the collaborative innovation of different institution supplies. The regulatory role of different types of institution supply in the process of GCP promoting green innovation of heavily polluting enterprises is not consistent. Specifically, under the joint action of environmental protection institution and innovation institution supply, environmental protection institution enhances the promotion effect of GCP on enterprise green innovation, while innovation institution supply weakens the promotion effect of GCP on enterprise green innovation. Therefore, we must build an efficient and complementary institution supply system to improve the systematization and matching of institutional implementation. Local governments should take the environmental protection institution supply as an important starting point to promote the green innovation of enterprises enabled by GCP. At the same time, we need to refine and adjust the supply system of innovation institution to alleviate the inhibition effect of innovation institution supply on the green innovation affected by GCP. This can give full play to the guiding role of government institution supply and promote heavily polluting enterprises to gradually realize the greening of production technology through green innovation, thus better meeting the challenges of green transformation and development in the new era.

(3) We need to formulate differentiated green credit policies for heterogeneous enterprises and regions to

achieve accurate positioning of green credit policies. Green technology innovation is not always the first choice for enterprises facing environmental regulation. The differences in ownership type, pollution intensity, and financial development will lead to different strategic choices of firms. The results of this study show that the impact of GCP on green innovation varies with the type of enterprise ownership and the level of financial development. Therefore, when formulating specific green credit policies, we should fully consider the heterogeneity of enterprises and regional heterogeneity and put forward targeted credit policies, actively encouraging and guiding different enterprises to carry out green technology innovation, rather than adopting a "one size fits all" approach.

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Declaration of Competing Interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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