

Article

Verifying the “Porter Effect” of Green Credit Policy on Upstream Suppliers in the Green Supply Chain

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Abstract: In striking contrast to the hot debate on the effect of the Green Credit Policy (GCP) on heavy-polluting enterprises (HPEs), little attention has been paid to the policy effect on upstream enterprises of HPEs in the green supply chain. Using the data of China’s A-share listed companies from 2009 to 2020 and regarding the promulgation of GCP as a quasi-natural experiment, we manually collect upstream suppliers providing source control and end-of-pipe treatments to HPEs and investigate the impact of GCP on the green innovation in these suppliers. Findings show that: (i) The GCP promotes green innovation in upstream suppliers of HPEs, especially those providing end-of-pipe treatments. Such findings hold after a series of robustness tests. (ii) Green innovation in these suppliers increases alternatively after promulgating the policy. A higher-than-average growth in green innovation in SOEs (state-owned enterprises) supplying advanced equipment for source control, non-SOEs providing end-of-pipe treatments, large-scale enterprises, as well as suppliers in cities with well-developed finance systems, suggesting that these enterprises are more likely to collaborate with HPEs under credit constraints. (iii) Insight into the potential mechanisms reveals that the credit policy can effectively improve internal environmental concerns and demand-induced trade credits of upstream suppliers to green the supply chain.

Keywords: green credit policy; green innovation; upstream suppliers; source control; end-of-pipe treatments



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1. Introduction

Increasing environmental constraints stand in stark contrast to the remarkable economic and social development in China [1–3]. To reduce pollution and promote green growth, the China Banking Regulatory Commission (CBRC) successively launched “Opinions on Implementing Environmental Protection Policies and Rules and Preventing Credit Risks” in 2007 and “Green Credit Guidelines” in 2012, the core framework of Green Credit Policy (GCP). The guidelines instruct financial institutions to provide more credit support to green enterprises while exerting an “environmental veto” to heavy-polluting enterprises (HPEs) in high-pollution, high-energy intensive, and overcapacity (“Two high and one overcapacity”) industries [4]. As a crucial component of environmental regulations in China, GCP has received considerable attention [5–8]. An important branch of literature focuses on the “Porter effect” or crowd-out effect of GCP on green innovation in HPEs, but few efforts have been placed on the impact on the upstream suppliers, the systematical investigation of which holds significant practical implications for optimizing the policy measures and promoting green innovation.

The effect of GCP on green innovation in upstream enterprises originates from the policy's innate advantages over the traditional regulatory model. Different from the formal governance of "command-and-control", GCP acts as an informal governance mechanism and has the dual functions of traditional finance and environmental regulation [9]. For one thing, according to the theory of relationship view [4], GCP plays an important role in internalizing environmental costs through the environmental cooperation of HPEs and upstream suppliers [9,10]. Upstream enterprises generally provide HPEs with source control and end-of-pipe treatments such as advanced facilities, equipment, sewage treatment technologies, etc. Compared with upstream suppliers, HPEs inevitably develop behavioral inertia in green transformation because of high costs and risk uncertainty. They tend to maintain original production methods with low production efficiency and high environmental costs [11]. Thus, the behavioral inertia and the R&D investment shrinkage of HPEs owing to credit limitation set an important basis for HPEs to turn to their suppliers for pollution abatement solutions [12].

For another, the credit policy solves the lack of incentives for the green production of both HPEs and their suppliers. The improvement in environmental performance is rewarded with more green credit at lower financing costs, which, in turn, ensures the supply of green technologies and guarantees successful collaboration in pollution control between HPEs and upstream suppliers [4,13]. Under this circumstance, upstream enterprises are induced to extend green production and promote technological progress through innovative R&D to meet the rising demand from HPEs. These green technological advances can bring long-term economic benefits to the green supply chain as a whole and minimize the risk of pollution during production activities. Therefore, under the credit policy, upstream suppliers are more likely to carry out green innovation.

Despite considerable literature concerning the effect of GCP on HPEs, GCP's innovation effect on upstream suppliers remains unexplored [14]. Most believe that green credit positively boosts energy efficiency [5], facilitates enterprise upgrading [6], and reduces pollution emissions [15], thus leading to the "Porter effect" [14,16]. Some others hold opposite views, believing that the policy impedes the green technology investments of HPEs and limits their green innovation capabilities [17,18]. Specifically, in the context of bank-centric financial structures, like China, loans are the predominant way for enterprises to obtain external financing [19]. Enterprises with access to bank loans are proven to be more productive [20,21]. However, when banks take a more cautious and critical attitude towards polluting firms, green innovation in not only HPEs but also the most relevant upstream suppliers will be greatly affected. Yet, thus far, whether GCP exerts an influence on green innovation in upstream suppliers remains unanswered [11].

To bridge this gap, we manually collect the most relevant upstream suppliers of HPEs and exploit the promulgation of GCP to establish a causal relationship between the policy and green innovation in upstream enterprises. More specifically, based on the unbalanced panel data of Chinese A-share listed companies from 2009 to 2020, we find that confronted with stringent credit control, upstream suppliers are more inclined to conduct green innovation to provide HPEs source control or end-of-pipe treatments. All other things being equal, the promulgation of GCP can explain 8.87 and 8.94 percent of green innovation variation of upstream suppliers for source control and end-of-pipe treatments, respectively, which are both statistically and economically significant. Besides, we also exploit an event study to test the parallel trend between upstream suppliers and other enterprises, the result of which implies that no significant difference has been found in green innovation performance between enterprises before the policy, while green innovation in these suppliers increases alternatively after the policy.

To validate our results, we conduct a series of robustness checks. We find that the “Porter effect” of the credit policy on upstream suppliers still holds and is quite robust. Delving into firm characteristics and financial environment, we detect a higher-than-average growth in green innovation in SOEs providing source control, non-SOEs providing end-of-pipe treatment systems, large-scale enterprises as well as suppliers in cities with well-developed finance systems, suggesting that these upstream enterprises are more likely to collaborate with HPEs to meet the regulation requirements. Insight into the potential mechanisms reveals that the credit policy can effectively improve the internal environmental concerns and demand-induced trade credits of upstream suppliers to green their supply chain.

In doing so, the marginal contributions of our research are as follows: Firstly, though the effect of credit policy on HPEs’ green innovation and pollution abatement has been well explored in prevailing literature, few scholars pay attention to the potential impact of GCP on upstream suppliers from a systematic perspective of the green supply chain. Given this, our study explores the “Porter effect” of GCP on upstream enterprises from a green supply chain perspective. Our contribution to revealing the gains from GCP varies widely among different enterprises and cities, provides a comprehensive evaluation of the credit policy, and proposes alternative viewpoints on green supply chain development. Secondly, the heterogeneous effect of GCP on different suppliers remains unexplored since few researchers have attempted to differentiate the roles between source control and end-of-pipe suppliers when confronting changes in credit supply. This study investigates the heterogeneous impacts of GCP on both source control and end-of-pipe suppliers to promote green innovation and establish a comprehensive evaluation system for GCP. Thirdly, the paper further examines the potential pathways of the policy on upstream suppliers’ green innovation performance, taking into account internal environmental concerns and demand-induced trade credits. In doing so, our work provides policymakers with theoretical support for further promoting green innovation, maximizing gains from credit policy, and achieving pollution abatement.

The rest of this research is arranged as follows: Section 2 presents a literature review and theoretical analysis. Section 3 outlines the research design, including model specification, variable calculation, and data processing. Section 4 analyzes the baseline results, a series of robustness tests, and heterogeneity tests. Section 5 explores the potential mechanisms. Section 6 concludes this study.

2. Literature Review and Hypotheses

Originates from “the Equator Principles”, GCP stipulates that banks and other financial institutions should take environmental problems and risks fully into consideration when allocating credit [11]. Aiming to encourage green and sustainable development through credit allocating and directing, the policy acts as an indispensable addition to the traditional environmental regulation systems [22,23]. Under the credit policy, HPEs and enterprises raise significant environmental risks, confront credit financing shrinkage, and increase the cost of pollution [24], while for enterprises in green environmental industries, the policy provides available credit support [25]. Increasing attention from scholars worldwide has been placed on this policy since the G20 agenda in 2016 put green finance in the spotlight [26]. Extant literature on GCP dives into its impact on industrial structure upgrading [27], the green economy development [28–31], corporate investment and financing [19,32], green transformation, corporate social responsibility [33,34], environmental pollution and carbon emissions [35–37], bank performance and asset quality [38,39], etc.

Scholars have generated divergent opinions regarding the effect of GCP on green innovation. According to the neoclassical economic theory, some scholars think that increasing

costs of compliance with environmental regulations impede enterprises' willingness and ability to innovate, thus inhibiting their innovation [40–42]. For instance, Wagner [43] suggested that the number of green patents underwent significant reductions because of environmental regulation; Stucki et al. [44] confirmed the crowd effect of environmental regulation on green innovation; Yu [15] revealed that GCP stifled HPEs' innovation through discouraging R&D investment and commercial bank loans. Moreover, Bartram et al. [45] found that enterprises confronted with credit limitations were more likely to relocate their polluting activities instead of engaging in innovation; Liu et al. [16] pointed out that investments in technological innovation would be diverted to invest in fixed costs such as sustaining operations improvement; Ge et al. [9] proven that GCP increased HPEs' financial hurdles and operations risk, and compels them to produce environmental friendly by allocating financial resources in a marketing-oriented manner. Literature in this stream coincides with studies on the effect of credit constraints on environmental innovations [46–48], emphasizing that HPEs, limited by the policy, may be forced into a vicious cycle of increasing financial constraints, reducing R&D investment, and then impairing innovation abilities.

Some others, however, support the “Porter hypothesis” and believe that stringent but properly designed regulations can promote environmental innovations, which may then partially or fully make up for the compliance cost [49–51]. A series of studies provides evidence for the “Porter hypothesis” and verifies the environmental impacts of regulations using indicators such as energy efficiency, emission density, and pollution cost [42,52–55]. For instance, Berrone et al. [52] discovered that environmental regulatory pressure indeed motivated green innovation in enterprises; Shen et al. [55] and Mi et al. [56] reached a similar conclusion on the positive effect of GCP on innovation. However, several studies also detect a U-shaped association between regulation and environmental innovations [5,57]. Besides, extant literature insists that GCP facilitates firms' green innovation performance, improves innovation quality, and promotes the low-carbon development of HPEs [58,59].

In stark contrast to the substantial literature evaluating the policy effect on HPEs, few studies place attention on HPEs' upstream suppliers, let alone the suppliers providing different environmental technologies. According to the “Porter hypothesis”, it is an inevitable choice for HPEs to conduct proactive environmental collaboration with their upstream suppliers to discover win–win solutions to the credit constraints [60], which is positively associated with increasing R&D investment in environmental technologies, such as source control and end-of-pipe treatments [61,62]. Early literature has provided theoretical support and benefits for adopting source control technologies as alternative solutions to end-of-pipe treatments [63]. Moreover, the merits of source control over end-of-pipe treatments are recognized, as the former has been proven to be positively linked to economic and environmental performance [64]. Nonetheless, some industries remain slow to embrace alternative control technologies because of organizational resistance and inertia in the supply chain [63]. The potential impacts of the credit policy on the environmental collaboration between HPEs and upstream suppliers for source control or end-of-pipe technologies make a great difference in the green innovation of these suppliers. Such a question should be investigated further.

Insufficient investigation arouses our interest in the innovation effects of GCP on upstream suppliers of both source control and end-of-pipe treatments in the product-based green supply chain. As mentioned earlier, the implementation of GCP motivates environmental collaboration between upstream suppliers and HPEs and stimulates green innovation in these suppliers. As environmental technologies, source control acts as an alternative solution to end-of-pipe treatments, both of which are vitally important to achieve pollution reduction in HPEs and promote green innovation in upstream suppliers

(see Figure 1). Based on the discussions above, we then put forward our hypotheses for empirical research.

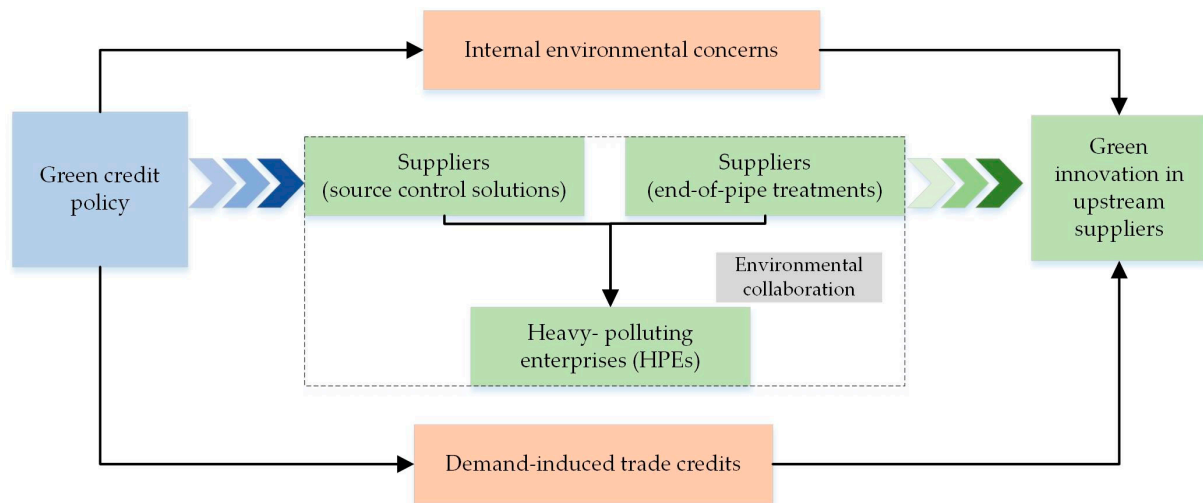


Figure 1. Theoretical framework.

Based on the review of existing literature, the implementation of GCP may have a “Porter effect” on upstream suppliers. On the one hand, credit support from the GCP for the environmentally friendly program may motivate upstream suppliers to engage in green innovation activities. On the other hand, the shrinking scale of commercial credit and the increasing cost of polluting activities compel HPEs to extend environmental responsibility to their upstream suppliers for source control or end-of-pipe solutions [65,66], thus inducing more R&D activities of suppliers. For instance, the development of advanced energy-saving machinery or pollution abatement devices (such as a catalytic converter) for HPEs by upstream suppliers eventually triggers environmental innovation. As Vachon [63] proven, in the product-based green supply, environmental collaboration of HPEs with their upstream suppliers is positively associated with greater R&D investment in pollution abatement technologies [67,68], which was classified as one of the critical success factors for green innovation [69], while the collaboration of HPEs with downstream customers has no such impact. Based on the above argument, we formulate our first hypothesis:

Hypothesis 1. *The implementation of GCP may stimulate environmental collaboration between upstream suppliers and HPEs, thus motivating green innovation in these suppliers.*

Moreover, GCP is likely to have heterogeneous effects on upstream suppliers of different ownership, scale, and areas. Generally, green innovation has high uncertainty and is, in particular, risky for non-state-owned enterprises (non-SOEs), small-scale enterprises, and those in backward areas since these enterprises face larger financial constraints and have less access to external finance [70]. Conversely, state-owned enterprises (SOEs) and large firms are more inclined to conduct R&D activities for low-carbon innovation because of the significant easing of financing constraints by implicit debt guarantees [71]. However, several studies hold contrary opinions and believe that state ownership and firm scale do not play a dominant role in the credit market, thus increasing financing constraints [72,73]. In the context of bank-centric financial structures, like China, non-SOEs and small enterprises usually confront the shortage of funds for green innovation, while GCP can help to provide fund support for pollution abatement solutions, including source control and end-of-pipe treatments, which in turn motivate enterprises’ R&D activities and innovation performance [74]. Additionally, well-developed financial systems facilitate bringing

GCP into full play; hence, upstream suppliers in these areas may be more motivated [75]. Accordingly, we propose the second hypothesis:

Hypothesis 2. *The effect of GCP on green innovation in upstream enterprises of SOEs, large-scale enterprises, and those in well-developed financial systems may be more significant.*

The “Port effect” of GCP is not straightforward, as internal environmental concerns and demand-induced trade credits probably play a role therein. As an institutional reform, the mechanism of GCP provides credit tilt to support environmentally friendly projects [76], stimulating enterprises to raise environmental awareness, which becomes more and more important for enterprises because of the growing demand for source control and end-of-pipe treatments from HPEs [77]. Besides, a strand of research reveals that upstream enterprises would extend trade credits to their customers when the latter confronts tight financial constraints [78–80]. Upstream suppliers for pollution abatement can postpone the due payments and provide non-trivial amounts of credit to HPEs. For HPEs limited by the policy, trade credits from upstream suppliers for purchasing source control and end-of-pipe treatments would be an imperfect alternative to bank credits [81]. Environmental collaboration between upstream suppliers and HPEs can not only green the supply chain but also help HPEs meet the requirements of GCP and motivate sustainable innovation in upstream suppliers. Therefore, we put forward the third hypothesis:

Hypothesis 3. *Increased environmental concerns and demand-induced trade credits play potential pathways in the “Porter effect” of GCP on upstream suppliers.*

3. Research Design

3.1. Model Specification

Consistent with relevant literature [8,12], we treat the GCP promulgated in 2012 as a quasi-natural experiment and utilize the difference-in-difference (DID) model to estimate the effect of GCP on green innovation in upstream suppliers.

Upstream enterprises supplying techniques and equipment for source control and end-of-pipe treatments to HPEs are regarded as treated groups and marked as Supply_sc and Supply_ep, respectively. The rest of the manufacturing enterprises are set as the untreated groups. Let Treat equal to 1 for treated groups and zero otherwise for untreated groups. Besides, let the GCP dummy variable (Time) equal 1 after 2012 and 0 before 2012. The intersection of Treat $\times$ Time is the core explanatory variable, which represents the potential effects of GCP on green innovation in upstream suppliers. The empirical Model (1) is shown as follows:

$$\text{LnGI}_{it} = \alpha + \beta \text{Treat}_i \times \text{Time}_t + \gamma X_{it} + \mu_i + \lambda_t + \delta_j + \varepsilon_{it} \quad (1)$$

where LnGI_{it} denotes the natural logarithm of a firm’s green innovation in year t , which is measured by the number of patent applications for green inventions. X_{it} incorporates a series of control variables to control firm-level unobserved heterogeneity, such as firm scale, age, the number of employees, capital structure, growth rate, return on assets, cash flow ratio, equity concentration, and capital intensity. μ_i , λ_t and δ_j represent firm, year, and industry fixed effects, respectively. ε_{it} is a random disturbance term. To avoid potential serial correlation and heteroscedasticity, we utilize cluster-robust standard errors, clustering at firm and year levels. The coefficient β is the focus of this study, which is estimated to identify the treatment effect of GCP on the green innovation in upstream suppliers of HPEs and reflects the average difference in the green innovation in enterprises in the treated groups and untreated groups pre- and post-GCP.

3.2. Variables

Green invention (GI). As in Tumelero et al. [82], green innovation in manufacturing enterprises is measured by patent applications of green invention. The main consideration of using invention rather than utility model patents is that the former for green technology innovation is generally believed to be more substantive than the latter [83]. Moreover, compared with granted patents, applied patents have been proven to be more accurate in assessing the innovation capability of listed manufacturing enterprises [84]. Figure 2 illustrates the time variation of green innovation in both treated and untreated groups pre- and post-GCP. In addition, we incorporate firm-level transfers of green technology as a proxy for green innovation in the robustness test section. Such a proxy is measured by the number of joint patent applications since joint innovation among companies facilitates the cross-organizational transfer of knowledge and technology [85].

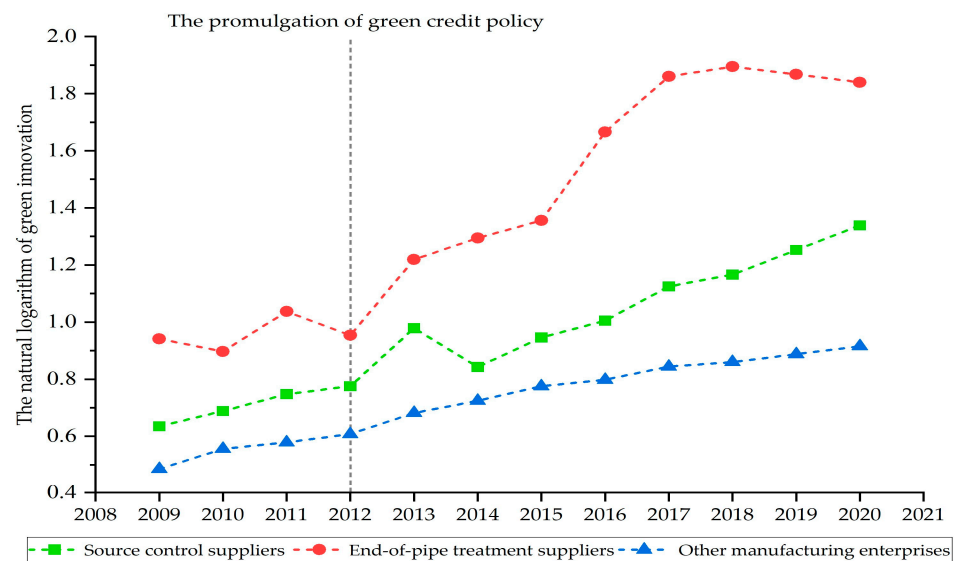


Figure 2. The time variation of green innovation in treated and untreated enterprises.

GCP. The core explanatory variable GCP is denoted by the intersection of $Treat \times Time$, where $Time$ equals 1 after the promulgation of GCP in 2012 and 0 before 2012, and $Treat$ equals 1 for treated groups and zero for untreated groups. Aside from suppliers providing end-of-pipe solutions to HPEs, some other manufacturing enterprises help HPEs upgrade facilities and optimize production processes to achieve source control. Therefore, the treated groups are further divided into two: suppliers for traditional end-of-pipe solutions ($Supply_ep$) and suppliers for source control ($Supply_sc$).

As to industry classification, this research classifies listed manufacturing enterprises into 14 industries. According to the “Industry Classification Management Catalogue for Environmental Inspection of Listed Companies” released by the Ministry of Environmental Protection in 2008, we take industries like textile, steel, and thermal power as HPEs. Correspondingly, suppliers in industries including general equipment (C34) and special equipment manufacturing (C35), which directly affect the production and energy efficiency of HPEs, are grouped into $Supply_sc$. According to the industry classification on platforms such as Oriental Fortune Capital, Tonghuashun, and Wind, enterprises in environmental protection and governance-related industries, such as garbage and sewage disposal, etc., are grouped into $Supply_ep$. To detect the environmental collaboration between upstream suppliers and HPEs, we manually collect the supplier information disclosed in corporate annual reports and select the most relevant suppliers. To avoid the potential bias

caused by overlap samples, we delete these enterprises that belong to both Supply_sc and Supply_ep groups.

Control variables. To investigate the treatment effect of GCP on green innovation in upstream supplies, we control for omitted variables across different manufacturing enterprises. As in most existing literature [86–89], we incorporate firm scale (Size), measured by the natural logarithm of total enterprise assets; firm age (Age), calculated by the natural logarithm of the difference between the current year and the year of establishment of the firm plus one; the number of employees (Labor), measured by the natural logarithm of the number of employees; capital structure (Lev), indicated by the ratio of total liabilities to total assets; firm growth (Growth), calculated by the growth rate of business revenue; return on assets (Roa), denoted by the ratio of net profit to average assets; cash flow ratio (Cashflow), signified by the ratio of cash flow in total assets; equity concentration (Top1), measured by the proportion of shares of the largest shareholder; capital intensity (Capital), calculated by the ratio of total assets to operation revenue; R&D investment (R&D_invest) measured by the nature logarithm of R&D expenditure; and R&D subsidies (R&D_sub) calculated by the natural logarithm of government subsidies for R&D activities.

3.3. Data

We use data from China's A-share listed companies from 2009 to 2020. The reason for selecting 2009 as the starting point lies in ruling out the possible impact of the 2008 financial crisis and other environmental policies, such as the Opinions on the Implementation of Environmental Protection Policies and Regulations against Credit Risks in 2007, released jointly by State Environmental Protection Administration, People's Bank of China, and China Banking Regulatory Commission. Besides, the reason for setting 2020 as the ending year is that the 14th Five-Year Plan for Green Industrial Development issued by the Ministry of Industry and Information Technology in 2021 was promulgated to implement new green financial tools to facilitate green development at the industrial level [90]. Hence, we do not incorporate observations in 2021 and beyond to ensure comparability.

The financial data of listed companies are mainly drawn from the China Stock Market and Accounting Research Database (CSMAR); relevant price indices source from China Economy Information Network (CEI); patent applications of enterprises are collected from the China Research Data Service Platform (CNRDS) and the State Intellectual Property Office (SIPO). The raw data are cleaned and processed as follows: observations including financial enterprises, ST, *ST, and PT enterprises, and those with seriously missing values are eliminated; all continuous variables are winsorized at 1% and 99% levels to avoid data noise and eliminate outliers. Further, we set 2009 as the base period and $CPI_{2009} = 100$ to eliminate the impact of inflation on variables like total assets, fixed asset investment, and other financial indicators of listed companies. Finally, we obtain the unbalanced data of 2868 listed companies and a total of 21,371 firm-year observations, where 360 in the Supply_sc group with around 2434 obs., 95 in the Supply_ep group with roughly 635 obs., and 2413 in the untreated group with approximately 18,302 obs.

3.4. Descriptive Analysis

The statistical description of the above variables is presented in Table 1. The average value of $LnGI$ in the Supply_sc group is 0.893, while this in the Supply_ep group is 1.678 and significantly higher. The average value of $LnGI$ in the untreated group is 0.761 and falls behind the Supply_sc and Supply_ep groups. The standard deviation of $LnGI$ is generally higher than group mean values, implying that the green innovation ability among different enterprises differs widely as individual enterprises may adopt different strategies to improve innovation ability when confronting policy challenges, such as GCP.

After scrutinizing the full data, we find that pre- and post-GCP, the mean values of *LnGI* in the Supply_sc group are 0.539 and 0.944, respectively. These in the Supply_ep group are 0.686 and 1.845, respectively, suggesting a dramatic improvement in green innovation, especially those in the Supply_ep group, which is more intuitively in Figure 2.

Table 1. Descriptive statistics.

Variables	Supply_sc (N = 2434)				Supply_ep (N = 635)				Untreated Group (N = 18,302)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
<i>LnGI</i>	0.893	1.085	0	4.775	1.678	1.408	0	4.762	0.761	1.112	0	4.762
<i>Size</i>	12.22	0.989	9.965	16.122	12.646	1.111	9.878	15.894	12.572	1.241	9.878	16.487
<i>Age</i>	2.775	0.352	1.099	3.555	2.849	0.301	1.792	3.434	2.821	0.374	1.099	3.555
<i>Labor</i>	7.358	0.964	4.673	10.574	7.115	1.079	4.407	10.716	7.532	1.221	4.094	10.716
<i>Lev</i>	0.378	0.187	0.028	0.892	0.478	0.185	0.044	0.905	0.42	0.208	0.028	0.905
<i>Growth</i>	0.174	0.371	−0.657	3.541	0.237	0.434	−0.633	3.133	0.178	0.427	−0.657	3.978
<i>Roa</i>	0.04	0.069	−0.506	0.233	0.039	0.042	−0.272	0.176	0.039	0.064	−0.506	0.233
<i>Cashflow</i>	0.039	0.064	−0.199	0.291	0.032	0.065	−0.191	0.291	0.046	0.072	−0.222	0.291
<i>Top1</i>	34.003	13.607	8.352	75.734	38.14	14.891	11.369	75.104	34.695	15.109	8.352	75.734
<i>Capital</i>	2.533	1.386	0.412	14.595	3.703	2.333	0.412	14.595	2.593	2.242	0.386	16.066
<i>R&D_invest</i>	8.475	1.302	0.000	13.347	7.295	2.235	0.000	17.448	7.212	3.239	0.000	24.391
<i>R&D_sub</i>	7.227	6.616	0.000	18.379	4.744	6.155	0.000	16.206	5.047	6.399	0.000	21.318

Source: Calculated by authors.

4. Results and Analysis

4.1. Baseline Regression

Table 2 reports the baseline results of the impact of GCP on green innovation in upstream suppliers of HPEs. Columns (1) and (2) estimate the treatment effects on the Supply_sc group, (3) and (4) estimate the treatment effects on the Supply_ep group. Columns (1) and (3) consider only *GCP*. On this basis, Columns (2) and (4) incorporate a couple of control variables, which allow us to explain a higher portion of the cross-sectional variation in our models, with adjusted R² reaching approximately 70%. Therefore, the following is the interpretation of results from Columns (2) and (4). The estimated coefficient of *GCP* in Column (2) is 0.089 and statistically significant at the 5% level. Similarly, the coefficient of *GCP* in Column (4) is also significantly positive, indicating that the promulgation of GCP promoted green innovation in upstream suppliers. Such results suggest that all other things being equal, the promulgation of GCP can explain 8.20 and 9.23 percent of green innovation variation of upstream suppliers providing source control and end-of-pipe treatments for HPEs, respectively. H1 is verified primarily.

Table 2. Baseline regression.

Variables	Supply_sc		Supply_ep	
	(1)	(2)	(3)	(4)
<i>GCP</i>	0.0732 (0.0511)	0.0890 ** (0.0423)	0.1856 ** (0.0869)	0.1300 * (0.0771)
<i>Size</i>		0.2208 *** (0.0191)		0.2271 *** (0.0195)
<i>Age</i>		0.1224 * (0.0703)		0.1448 ** (0.0733)
<i>Labor</i>		0.0489 *** (0.0122)		0.0514 *** (0.0122)
<i>Lev</i>		−0.0364 (0.0513)		0.0099 (0.0511)
<i>Growth</i>		−0.0327 *** (0.0119)		−0.0285 ** (0.0117)

Table 2. Cont.

Variables	Supply_sc		Supply_ep	
	(1)	(2)	(3)	(4)
<i>Roa</i>		0.0841 (0.0911)		0.1040 (0.0992)
<i>Cashflow</i>		−0.1128 (0.0718)		−0.1177 (0.0750)
<i>Top1</i>		−0.0001 (0.0008)		0.0003 (0.0008)
<i>Capital</i>		−0.0122 *** (0.0037)		−0.0126 *** (0.0037)
<i>R&d_invest</i>		0.0526 *** (0.0050)		0.0522 *** (0.0049)
<i>R&D_sub</i>		0.0020 ** (0.0009)		0.0022 ** (0.0009)
Constant	0.4996 *** (0.0086)	−3.3286 *** (0.2705)	0.5257 *** (0.0081)	−3.4932 *** (0.2737)
Firm FE	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	20,090	20,073	18,356	18,339
R2_Adj	0.6804	0.6999	0.6898	0.7105

Notes: The dependent variable in this table is the natural logarithm of green innovation; robust standard errors are clustered at the firm- and year level and reported in parentheses; ***, **, and * represent 1%, 5%, and 10% significance levels, respectively.

Besides, a higher coefficient value of 0.130 in Column (4) than that in Column (2) suggests a larger treatment effect of GCP on green innovation in manufacturing enterprises in the Supply_ep group than those in the Supply_sc group. A possible explanation may be that advanced production facilities and equipment for source control would be put into use for a depreciation period of at least 10 years, the inertia which implies that it is hard to replace them shortly when the policy has changed. The situation is different in enterprises of the Supply_ep group. The obsolescence of equipment and facilities, accompanied by increasing pressures on pollution control, spurs change in heavily polluting industries. Most low-tech HPEs have to rely on end-of-pipe solutions provided by upstream suppliers to meet GCP requirements. Therefore, enterprises in the Supply_ep group are more susceptible to credit policy shock and have more incentives to improve their green innovation ability than enterprises in the Supply_sc group.

The results of control variables differ widely. Coefficients in front of *Size*, *Age*, *Labor*, *R&d_invest*, and *R&D_sub* turn out to be significantly positive, while coefficients of *Growth* and *Capital* are significantly negative in both Columns (2) and (4), implying that larger scale assets, longer duration in the market, more employee, increasing R&D investment and subsidies contribute to improving green innovation ability. In contrast, *Growth* and *Capital* play negative roles in green innovation since enterprises with higher revenue growth rates and capital intensity are generally in industries with strong entry barriers. Hence, these enterprises have less incentive to innovate without the threat of a large number of new entrants. The rest of the control variables remain statistically insignificant in our model.

4.2. Parallel Trend Test

An important prerequisite for using the DID model is the parallel-trend assumption. Our research indicates that the green innovation in the treated group and untreated group presents no difference before GCP. Failing to satisfy this assumption would lead to bi-

ased estimations. To test whether the parallel trend assumption is satisfied, Model (2) is constructed:

$$LnGI_{it} = \alpha + \sum_{k=1}^3 \beta_k before_{it}^k + \sum_{l=0}^8 \delta_l after_{it}^l + \gamma X_{it} + \mu_i + \lambda_t + \sigma_j + \varepsilon_{it} \quad (2)$$

where $before_{it}^k$ denotes the interaction term of dummy variables of year and treated group in year t pre-GCP. $before_{it}^k$ equals 1 if firm i belongs to the treated group; otherwise, it is zero. Similarly, $after_{it}^l$ signifies the interaction term in t post-policy and equals 1 when firm i is in the treated group; otherwise, it is zero. The starting year of 2009 is set as the base period for the parallel trend test. If the coefficient estimates of β_k in each period pre-GCP are proven to be insignificant and close to zero, while the estimates of δ_l post-GCP are statistically significantly different from zero, then the parallel trend assumption is satisfied.

As presented in Figure 3, lower boundaries of the 90 percent confidence intervals denoted by black dash lines are below 0 before GCP, suggesting that there is no significant difference in green innovation between treated and untreated groups; hence, the ex-ante parallel trend assumption is satisfied. After the promulgation of GCP, the treatment effect on the Supply_sc group remains statistically significant until $l = 7, 8$. Differently, the treatment effect on the Supply_ep group shows a time lag and is insignificant until $l = 5, 6, 7, 8$. Such results reveal that source control and end-of-pipe solutions play an alternative role after GCP. The possible reason may be that initial pressure brought by GCP induces a sudden surge in demand for advanced production facilities and equipment for source control [8], which stimulates the green innovation in suppliers in the Supply_sc group. However, accompanied by the obsolescence of these equipment and facilities over time, such demand shrinks, and investments in end-of-pipe treatments and techniques increase gradually to play a dominant role in meeting policy requirements, spurring enterprises in the Supply_ep group to improve their green innovation. To enhance the robustness of the model assumption, we further explore the parallel trends in different regions (eastern and non-eastern areas) and industries (high-tech and non-high-tech industries), the results of which are broadly in line with Figure 3.

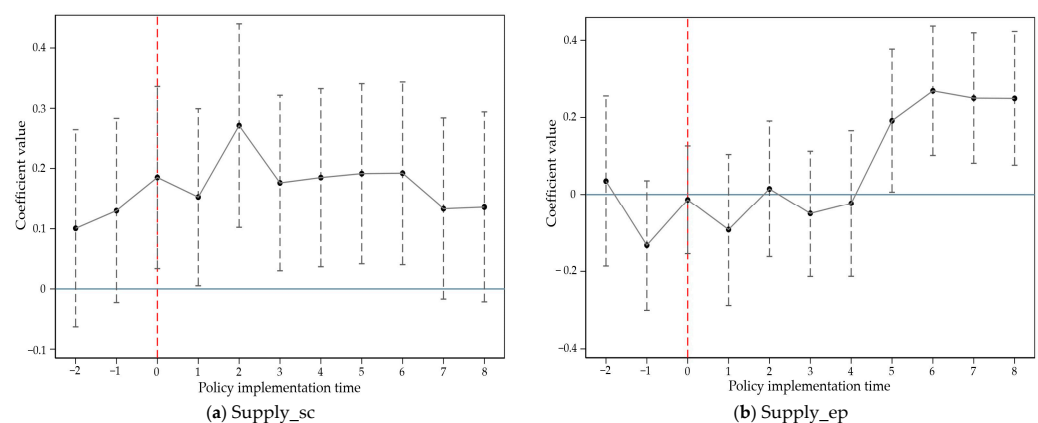


Figure 3. Parallel trend test. Notes: The vertical dash lines in red denote the current year of GCP promulgation. If the lower boundaries of the 90 percent confidence intervals represented by vertical dash lines in black are below 0, the coefficients are insignificant; if the lower bounds of the black dash lines are above 0, the coefficients are significant.

4.3. Robustness Test

Construct fictitious treated groups. To avoid omitted bias in the baseline regression due to unobservables, a fictitious treated group is constructed through random sampling concerning Ferrara et al. [91]. We estimate Model (1) in batches and repeat 500 times to obtain estimates of the treatment effect, as shown in Figure 4. The coefficients of random

samples are proven to be insignificant and close to 0, suggesting that the promulgation of GCP has hardly any effect on green innovation in enterprises in untreated groups.

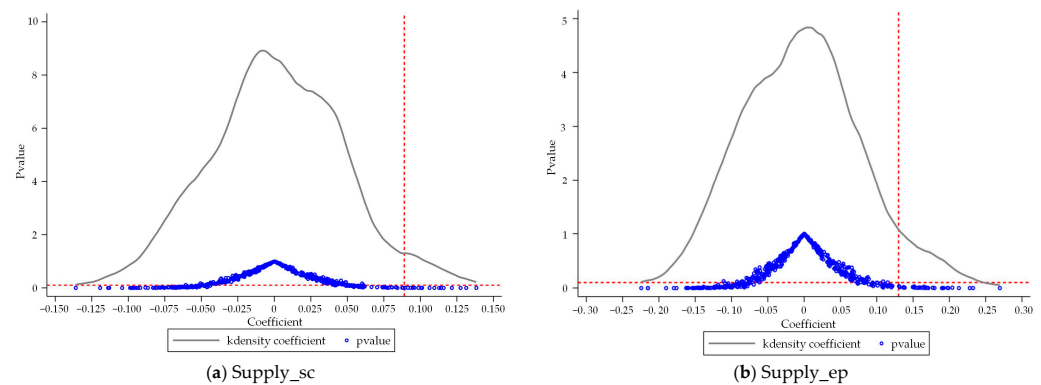


Figure 4. Placebo test. Notes: The vertical dash lines represent coefficients of GCP estimated from Model (1); horizontal dash lines denote a 10% significant level.

Propensity Score Matching DID (PSM-DID). To address potential self-selection and endogeneity problems associated with non-random grouping, the PSM-DID method is used to avoid sample selectivity bias. Specifically, we take the control variables in the baseline model as matching variables and utilize the logit model to calculate the propensity score. Then, we exploit the K-nearest neighbor method to select enterprises from the untreated group that share common characteristics with those in the treated group. The estimated results are shown in columns (1) and (4) of Table 3. The positive treatment effect of GCP on green innovation in enterprises in both Supply_sc and Supply_ep groups still holds, a significant level of which becomes higher after eliminating the self-selection problems.

Eliminate relevant policy interference. We attempt to eliminate relevant policy interference as follows: (i) The Law of the People's Republic of China on Environmental Protection (EPL), enacted in 2015, puts forward higher requirements on enterprises' pollution control and reduction behaviors. To eliminate the potential effect of EPL on enterprises' green innovation performance, we delete observations in 2015 and subsequent years. (ii) Green Finance Reform and Innovation Pilot Zone in 2016. Since then, China has set up green finance reform and innovation pilot zones in nine cities of six provinces. This may also bring about a change in the development of green innovation in the pilot areas. Therefore, we further exclude manufacturing enterprises in pilot areas to rule out the policy effect. Then, we estimate Model (1) with the rest of the observations. The results are reported in Columns (2) and (5) of Table 3, the coefficients of which are still significantly positive, suggesting that the effect of GCP on upstream supplies in both Supply_sc and Supply_ep groups remains hold.

Lagging effect of GCP. Given the great uncertainty about the green innovation process, it usually takes a long time to make substantive progress. Hence, we re-estimate Model (1) with a lagged dependent variable green innovation ($t - 1$), and the results are shown in Columns (3) and (6) of Table 3. The coefficients of GCP are still significant and positive, verifying again H1.

The transfers of green technology. As an alternative indicator for green innovation, we treat the firm-level transfers of green technology as the dependent variable and re-estimate Model (1). As can be seen from Table 3, the coefficients upon GCP in GI_Transfers columns remain statistically positive and significant, suggesting H1 holds.

Table 3. Robustness tests.

Variables	PSM-DID		Policy Interference		Lagging Effect	
	Supply_sc	Supply_ep	Supply_sc	Supply_ep	Supply_sc	Supply_ep
GCP	0.1023 *	0.3445 **	0.0918 **	0.1788 **	0.0822 **	0.1598 **
	(0.0588)	(0.1582)	(0.0450)	(0.0833)	(0.0406)	(0.0729)
Constant	−3.1248 ***	−2.9552	−3.3350 ***	−3.5041 ***	−2.8063 ***	−2.8358 ***
	(0.7185)	(2.3031)	(0.2707)	(0.2753)	(0.2826)	(0.2721)
Controls	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Observations	3619	805	18,920	17,278	18,694	18,594
R2_Adj	0.7210	0.7608	0.7029	0.7142	0.7145	0.7191
Variables	GI_Transfers		IV_2SLS			
	Supply_sc	Supply_ep	Supply_sc Stage 1	Supply_sc Stage 2	Supply_ep Stage 1	Supply_ep Stage 2
GCP	0.0390 **	0.0719 ***		0.0991 **		0.3112 ***
	(0.0187)	(0.0267)		(0.0462)		(0.1139)
GCP_mean			0.9257 ***		0.8721 ***	
			(0.0163)		(0.1311)	
Constant	−0.6152 ***	−0.5876 ***	0.0274	−3.9505 ***	0.0530 ***	−3.8875 ***
	(0.0906)	(0.0959)	(0.0364)	(0.2043)	(0.0158)	(0.2203)
Controls	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Kleibergen–Paap rk LM			10.759 ***		11.243 ***	
Cragg–Donald Wald F			2981.649		42.150	
Observations	18,697	17,148	20,373	20,073	18,596	18,339
R2_Adj	0.4425	0.4520	0.9490	0.0603	0.9361	0.0657

Notes: The dependent variables (DV) in this table are the natural logarithm of green innovation except the GI_Transfers columns and the first stage of the IV estimation; DV of the former are green technology transfers while the latter are the two-digit industry-year mean value of GCP; robust standard errors are clustered at the firm- and year level and reported in parentheses; ***, **, and * represent 1%, 5%, and 10% significance levels, respectively.

Instrumental variable (IV) methods. To deal with the potential endogeneity of the policy, we apply instrumental variable methods (2SLS) to further validate the robustness of the causal relationship. Specifically, this paper employs the two-digit industry-year mean value of GCP [92]. To some extent, the overall situation of two-digit industries affected by the credit policy can predict whether individual firms within the industry would be subject to the policy shocks but cannot directly influence firms' green innovation activities, thus satisfying both the IV estimation assumptions on instrument relevance and exogeneity. As shown in Table 3, the Kleibergen–Paap rk LM statistic in the first stages turns out to be significantly positive, indicating that the instrumental variables are not under-identified. The Cragg–Donald Wald F statistic exceeds all critical values, rejecting the null hypothesis of “weak instrumental variables” and thus confirming the validity of the instrumental variables. The IV estimations of the second stage suggest that the coefficients of GCP are significant and positive, implying that H1 still holds.

4.4. Heterogeneity Analysis

Enterprise ownership. Upstream enterprises with different ownerships may behave differently in terms of green innovation when confronting GCP. To investigate the heterogeneous treatment effect on suppliers with different ownerships, we classify these enterprises into two groups, SOEs and non-SOEs, and re-estimate Model (1) separately. Results are

presented in Figure 4. The coefficients of GCP are significantly positive in the case of SOEs in the Supply_sc group and non-SOEs in the Supply_ep group but insignificantly negative in the case of non-SOEs in the Supply_sc group and SOEs in the Supply_ep group, signifying that the implementation of GCP promotes the green innovation performance of SOEs supplying equipment for source pollution control as well as green innovation activities of non-SOEs providing end-of-pipe treatment systems.

Firm scale. Different firm scales imply different resource endowments and risk preferences. To explore the heterogeneous effects on upstream suppliers of different scales, we divide these samples into large- and small-scale groups according to median assets and then re-estimate Model (1) separately. Results are also shown in Figure 4. The GCP coefficients of large-scale enterprises in both Supply_sc and Supply_ep groups are statistically significant and positive, suggesting that GCP motivates more green innovation activities in large-scale suppliers than in small-scale ones.

Financial environment. The financing environments of enterprises differ widely due to widening regional disparities. More accessible and affordable financial systems in developed areas help to effectively alleviate financing constraints and implement GCP. Using “the ratio of the year-end RMB loan balance of financial institutions to GDP” to measure the financial environments of prefecture-level cities, we divide these enterprises into two groups according to the median of the ratio: enterprises operating in well-developed and less-developed financial systems. Results for each group are illustrated in Figure 5. The GCP estimates of suppliers in cities with well-developed financial systems turn out to be significantly positive, while estimates are insignificant for suppliers in cities with backward financial systems. Therefore, H2 holds.

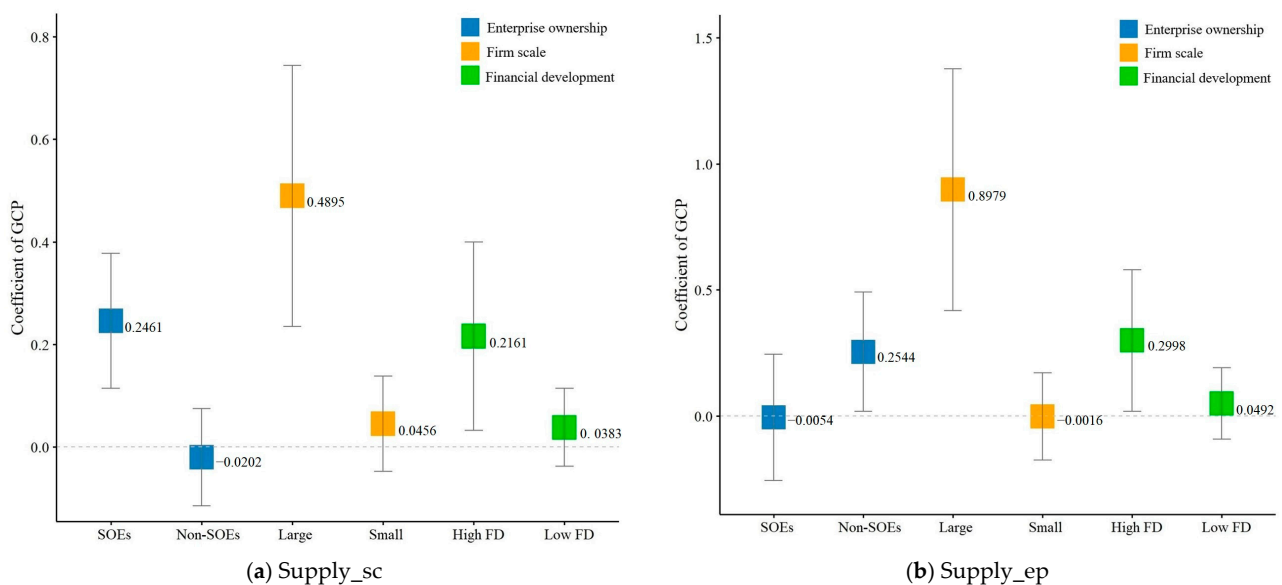


Figure 5. Heterogeneity analysis. Notes: If the lower boundaries of the 95 percent confidence intervals represented by vertical dash lines in black are below 0 (the horizontal dash lines), the coefficients are insignificant; if the lower boundaries of the black dash lines are above 0, the coefficients are statistically significant.

5. Potential Pathways

As mentioned previously, we investigate two potential pathways through which GCP influences green innovation in upstream suppliers: demand-induced trade credits (Credit) and the internal environmental concerns (Concerns) brought about by GCP. Following Wang

and Yao [83], we construct Model (3) and (4) based on Model (1) and estimate them jointly to verify the transmission mechanism of GCP on green innovation in upstream suppliers.

$$M_{it} = \alpha_1 + \alpha_2 DID_{it} + \gamma X_{it} + \mu_i + \lambda_t + \delta_j + \varepsilon_{it} \quad (3)$$

$$LnGI_{it} = \beta_1 + \beta_2 DID_{it} + \beta_3 M_{it} + \gamma X_{it} + \mu_i + \lambda_t + \delta_j + \varepsilon_{it} \quad (4)$$

where M_{it} denotes the proxy variables for trade credits and concerns, the former of which can be further subdivided into two parts. One part is the trade credits (*Credit_sc*) provided by upstream enterprises in the Supply_sc group to credit-limited HPEs, such that HPEs can upgrade their equipment to improve energy efficiency and reduce pollution. The other part is the trade credits (*Credit_ep*) provided by upstream enterprises in the Supply_ep group to HPEs, such that HPEs can invest more in end-of-pipe treatments. The rest of the variables remain unchanged, as in Model (1).

5.1. Internal Environmental Concerns

The internal environmental concerns of upstream enterprises in Supply_sc and Supply_ep are measured by the frequency of environment-related keywords in the total number of words in the annual reports of listed companies. The regression coefficients of GCP are shown in Table 4. The GCP coefficients in Columns (1)–(4) are all significantly positive, at least at 10% levels, indicating that with the implementation of GCP, manufacturing enterprises are more concerned about pollution control and environmental protection to green their supply chain. Particularly, the growing enterprise concern of suppliers in the Supply_ep group motivates more green innovation.

Table 4. Internal environmental concerns.

Variables	Supply_sc		Supply_ep	
	(1) <i>Concerns_sc</i>	(2) <i>LnGI</i>	(3) <i>Concerns_ep</i>	(4) <i>LnGI</i>
GCP	0.1436 *** (0.0461)	0.0700 * (0.0404)	0.1774 ** (0.0746)	0.1394 * (0.0807)
<i>Concerns_sc</i>		0.0180 * (0.0094)		
<i>Concerns_ep</i>				0.0164 * (0.0099)
Constant	0.3149 (0.2525)	−3.6403 *** (0.2974)	0.3414 (0.2676)	−3.7026 *** (0.2941)
Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	17,969	17,672	16,314	16,060
R2_Adj	0.6445	0.6961	0.6565	0.7113

Notes: Robust standard errors are clustered at the firm- and year level and reported in parentheses; ***, **, and * represent 1%, 5%, and 10% significance levels, respectively.

5.2. Demand-Induced Trade Credits

An investigation for bilateral verification is conducted from both the supply side and the demand side. For suppliers providing source control and end-of-pipe treatments based on trade credits, the proxy variables for *Credit_sc* and *Credit_ep* are measured by the ratio of accounts and notes receivable to gross revenue. For HPEs, the introduction of advanced equipment generally aims to improve the efficiency of energy utilization to achieve source control. Therefore, the proxy variable of *H_Credit_sc* is calculated by the ratio of total asset income to energy consumption; the growing demand for more opportunities for end-of-

pipe treatment is commonly accompanied by increasing investment in sewage discharge equipment and end-of-pipe abatement technologies, etc., which is used as a proxy variable for *H_Credit_ep*.

The estimates are presented in Table 5. The coefficients in front of *GCP* and *Credit_sc* in Columns (1) and (2) are all significantly positive at the level of 1%. The results of the *Supply_ep* group turn out to be the same, as shown in Columns (3) and (4), suggesting that the promulgation of GCP can effectively improve trade credits from upstream suppliers to their HPE customers. Growing demand for both source control and end-of-pipe treatment systems stimulates green innovation in upstream suppliers. From the demand side, the coefficients of GCP are proven to be significantly positive in the case of *H_Credit_sc* and *H_Credit_ep* yet significantly negative in the case of *LnGI*, verifying that the implementation of GCP indeed compels HPEs to upgrade their production equipment for higher energy efficiency, at the same time spurs more investments in end-of-pipe abatement, verifying again the results in Column (1) and (3). The significant negative coefficient of GCP in Column (7) confirms the inhibitory effect of the policy on HPEs. By far, H3 has also been proven to be true.

Table 5. Demand-induced trade credits.

Variables	Supply_sc		Supply_ep		Demand_HPEs		
	(1) <i>Credit_sc</i>	(2) <i>LnGI</i>	(3) <i>Credit_ep</i>	(4) <i>LnGI</i>	(5) <i>HCredit_sc</i>	(6) <i>HCredit_ep</i>	(7) <i>LnGI</i>
GCP	0.0668 *** (0.0127)	0.0751 * (0.0418)	0.0236 ** (0.0111)	0.1281 * (0.0766)	0.6717 * (0.3486)	0.3314 *** (0.0859)	−0.0992 ** (0.0441)
Credit_sc		0.2058 *** (0.0345)					
Credit_ep				0.1630 *** (0.0370)			
Constant	−0.1185 ** (0.0580)	−3.2934 *** (0.2709)	−0.0385 (0.0404)	−3.4568 *** (0.2744)	19.0281 *** (6.6364)	0.0790 (0.4545)	−3.0795 *** (0.2456)
Controls	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES
Observations	20,332	20,032	18,555	18,298	537	25,073	24,755
R2_Adj	0.8098	0.7011	0.8381	0.7113	0.8671	0.3765	0.6879

Notes: The classification of HPEs is mainly based on the “Guidelines on Industry Classification of Listed Companies (Rev. 2012)” and the “Industry Classification Management Catalogue for Environmental Inspection of Listed Companies”. After processing and cleaning, 889 HPEs are ultimately obtained, with a total of 7182 enterprise-year samples, and the untreated group remains the same, as mentioned in Section 3. Robust standard errors are clustered at the firm- and year level and reported in parentheses; ***, **, and * represent 1%, 5%, and 10% significance levels, respectively.

6. Discussion

To verify the “Porter effect” of GCP on green innovation in upstream enterprises from the perspective of green supply chains, this research takes the credit policy as a quasi-natural experiment and utilizes the DID model to verify the impact of the policy on the green innovation in listed manufacturing enterprise supplying source control solutions and end-of-pipe treatments to HPEs.

6.1. Conclusions and Implications

The results suggest that the credit policy improves the green innovation performance of upstream enterprises, in particular those in the *Supply_ep* group. A larger treatment effect on the *Supply_ep* group than the *Supply_sc* group indicates that enterprises in the *Supply_ep* group are more susceptible to the credit policy and have more incentives to

improve their green innovation ability. These conclusions are buttressed by a series of rigorous robustness tests. Source control and end-of-pipe solutions play an alternative role in green innovation after GCP. The initial pressure brought by GCP induces a sudden surge in demand for advanced production equipment for source control. However, such demand shrinks, accompanied by the obsolescence of this equipment over time. Then, end-of-pipe treatment investments and techniques increase gradually to meet policy requirements, spurring green innovation in enterprises in the Supply_ep group. The innovation effect is more significant in the case of SOEs supplying equipment for source control, non-SOEs providing end-of-pipe treatment systems, large-scale enterprises, and cities with well-developed financial systems. Moreover, the promulgation of GCP can effectively improve environmental concerns and the trade credit supply of upstream enterprises, thus stimulating green innovation.

Important implications can be drawn from these findings. First of all, the systematic evaluation of the impact of GCP entails investigating the policy treatment effect on innovation from a green supply chain perspective rather than solely focusing on HPEs. Our research on the “Porter effect” of GCP on upstream enterprises defends a reasonable and moderate credit limitation to motivate joint collaborative efforts among enterprises. For one thing, the policy-induced demand for advanced equipment and green technologies calls for collaboration between upstream suppliers and HPEs, which have to adopt green techniques and upgrade equipment; for another, the alternative roles of source control solutions and end-of-pipe treatments suggest that upstream enterprises in Supply_sc and Supply_ep groups complement each other. Therefore, a comprehensive system of policy evaluation in green supply chain collaboration needs to be established, particularly the essential role upstream suppliers play therein.

Given the significant innovation effect of GCP on specific enterprises, the way to improve green innovation is to cultivate an environmental innovation ecosystem in which SOEs supply equipment for source control and non-SOEs provide end-of-pipe treatment systems. Meanwhile, large-scale enterprises, as well as those in cities with well-developed financial systems, take the lead, while non-SOEs supplying source control solutions, SOEs providing end-of-pipe treatments, small-scale enterprises, and those in cities with backward financial systems follow behind. In doing so, credit support for the policy should focus on improving the financial environment and stimulating upstream suppliers of SOEs and large-scale enterprises to enter industries such as energy conservation, consumption reduction, and coordinated carbon reduction. Also, these small-scale and non-SOEs should be given access to green subsidies and credits to adopt advanced green techniques, thus accelerating the dissemination of green innovation. Furthermore, motivating the trade credit supply and environmental concerns of upstream enterprises stimulates green technology development of the green supply chain and improves environmental performance. Specifically, greater attention should be given to enhancing subsidies and credit support, as well as addressing internal environmental concerns.

In addition, for upstream suppliers with higher levels of technology or market positions, to make full use of GCP is to actively apply for special green credit, green the supply chain through green finance and procurement agreements, strengthen data monitoring and information disclosure, and participate in the formulation of GCP and industry standards. Meanwhile, for upstream enterprises with low and medium technology levels or market positions, it is essential to accelerate technology upgrading through technology introduction, cooperation, and participating in innovation alliances dominated by high-tech companies, and enhance the availability of green credit to ease credit constraints by strengthening environmental disclosure. Through joint efforts with green supply chain members, these firms

can not only achieve their green innovation but also drive the sustainable development of the entire supply chain.

6.2. Limitations and Future Research Directions

Our investigation into the “Porter effect” of GCP from the perspective of green supply chains also has some limitations: First, due to the limited data availability for non-listed companies, the findings of this study regarding the impact of GCP on the green innovation of upstream suppliers apply only to listed companies. The applicability of these findings to non-listed companies remains to be further explored. Moreover, a wider range of empirical evidence could be obtained if the research samples were expanded to include more non-listed companies in the future. Second, during the period from 2009 to 2020, relevant government departments released several environmental policies and regulations to combat severe environmental pollution problems. Although this study employs a wide variety of robustness tests, it is still difficult to completely exclude the potential interference of these environmental policies. Hence, more accurate identification methods, including machine learning methods and causal discovery tools, should be employed in future studies to evaluate the policy effects. Third, this study focuses solely on the impact of the credit policy, the implementation of which requires the coordination of other environmental regulations. Thus, the cooperative effects of the policy on the green innovation of upstream suppliers need to be further investigated.

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