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Under the "Dual-Carbon" Goal: Green Credit Policy and High-Quality Enterprise Development in China

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Abstract: Given the context of "carbon peaking" and "carbon neutrality" goals, advancing the growth of green finance stands as a crucial agenda to bolster the high-quality advancement of China's economy in the contemporary epoch. Green credit is a remarkable milestone in pursuing the "Dual-carbon" emissions reduction objective and promoting high-quality development. Empirically, scant information exists regarding the correlation between GCP and the high-quality development of heavily polluting enterprises (HPEs). Using panel data from Chinese Lushan A-share listed enterprises spanning 2005 to 2022, this study employs the difference-in-difference model to evaluate the impact of the green credit policy (GCP) on HPEs. Our results show that after the implementation of GCP, the high-quality development of HPEs increased by 9.08% compared to non-HPEs. Despite considering multiple potential confounding factors, the conclusion remains unchanged. The positive effect is particularly pronounced among non-state-owned enterprises characterized by high carbon emissions and in the eastern region. The mechanism analysis indicates that GCP plays a role in influencing the high-quality development of enterprises by promoting low-carbon technological progress. This study establishes a foundation for making informed decisions in optimizing the green financial policy system to effectively enhance the high-quality development of enterprises in China and other developing countries.

Keywords: dual-carbon targets, green credit policy, low-carbon technological progress, difference-in-difference model, China

1. Introduction

In 2020, China made a significant global commitment to achieve the goals of "carbon peak" and "carbon neutrality". The systematic and leadership aspects of the "Dual-carbon" objective will promise reduced carbon emissions, improved enterprise quality, enhanced industrial quality, and a positive impact on China's ecological environment [1, 2]. The highly polluting industries within China's economic structure, a key area of energy and resource consumption, pollutant emissions, and a major contributor to carbon emissions, necessitate a transition towards a low-carbon economy [3].

Green finance acts as a bridge between ecological sustainability and economic growth, serving as an instrumental tool in realizing the objectives of dual-carbon development. In 2012, the former China Banking Regulatory Commission issued the "Green Credit Guidelines", which mandate that banking institutions actively adjust their credit structure by incorporating green credit principles. Green credit policy (GCP) encompasses policies whereby banks and other financial institutions offer advantageous low-interest loans to enterprises or projects that are environmentally friendly and low-carbon.

Concurrently, banks and other financial institutions enforce loan constraints and impose elevated interest rates on project investments and working capital for enterprises with significant pollution and high-energy consumption. The primary goal of implementing GCP at the micro-level is to facilitate energy conservation and emission reduction and promote the transformation and upgrading of enterprises. At the macro-level, the ultimate objective is to accomplish high-quality economic development.

The implementation of the GCP significantly enhances the availability of financing for green enterprises. Notably, private green enterprises exhibit greater responsiveness to the policy measures regarding financing accessibility than their state-owned counterparts [4, 5]. Similarly, GCP can result in a noticeable financing penalty effect and investment inhibition effect specifically targeted at heavily polluting enterprises (HPEs) [6]. Furthermore, implementing the GCP can effectively stimulate the green innovation of enterprises, leading to divergent policy effects on the innovation performance of industries subject to restrictions and unrestricted restrictions [7, 8]. Total factor productivity (TFP) indicates technological advancement and resource allocation efficiency, making it valuable for reflecting macro-policy objectives. Additionally, HPEs are critical in driving economic transformation and fostering upgrades.

The impact of GCP on firms' TFP has yet to be explored in the literature. The existing studies closely examine the effects of GCP on industrial structure and efficiency [9]. Most of these studies conclude that GCP influences industrial structure and facilitates industrial upgrading through financial channels, ultimately optimizing the overall economic structure and leading to a mutually beneficial outcome for the environment and the economy [10–12]. However,

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empirical evidence in the literature, based on microenterprise data, indicates that the credit constraint mechanism hampers technological innovation in HPEs [13]. Furthermore, implementing a GCP does not necessarily lead to the Porter effect [14]. These findings demonstrate that the existing literature has yet to reach a definitive conclusion regarding the relationship between GCP and enterprises' pursuit of high-quality development.

The research question is to investigate if the GCP will let HPEs undertake technological innovation to align with the green and low-carbon economy requirements. Subsequently, will they receive preferential access to credit resources, thereby facilitating the optimization and upgrading of their respective industries? This, in turn, would foster high-quality enterprise development and achieve mutual benefits for both the economy and the environment. Additionally, does the role of GCP display any asymmetric effects across different types of enterprises? The resolution of the queries above is crucial for harnessing the transformative potential of HPEs and achieving a mutually beneficial economic and environmental performance.

GCP is an innovative tool for environmental and climate governance. Extensive domestic and foreign research has made significant progress in assessing its impact on enterprises, with a particular focus on China's HPEs. However, the existing studies in this field have certain areas for improvement. Firstly, they primarily concentrate on enterprises' financial performance or technological innovation, neglecting the comprehensive development of the enterprises. Secondly, they fail to account for the variations in the implementation effects of the policy due to geographic and ownership differences among HPEs. Therefore, further empirical evidence is required to explore the impact of these variables.

Drawing on the context of the "Dual-carbon" goal, this study employs TFP as an indicator to comprehensively assess the high-quality development of enterprises. The objective is to examine the effectiveness of GCP at the micro-level, specifically focusing on its impact on listed companies operating within China's HPEs. Moreover, we explore the impact mechanism through an analysis of technological innovation, which showcases the incentivizing effect of low-carbon technological advancements. Subsequently, we investigate the impact of GCP on listed companies within China's HPEs by considering variations in geographic and ownership characteristics. Next, we examine the underlying mechanism of influence at the technological innovation level, reflecting the incentivizing effect through advancements in low-carbon technology. Furthermore, we analyze the impact of inter-enterprise heterogeneity on the policy's effectiveness, considering three dimensions: enterprise ownership, regional factors, and carbon emissions. This study contributes to the existing research on GCP by comprehensively evaluating the heterogeneity effect of the GCP among enterprises [15]. Also, the study offers substantial empirical evidence and serves as a valuable reference for fostering green financial policies and promoting the sustainable development of enterprises [16].

The remainder of the paper is organized as follows: Section 2 describes the literature review; Section 3 explains the methodology and analysis; Section 4 shows the empirical results; Section 5 presents the discussion; Section 6 is the conclusion and future works.

2. Literature Review

Many scholars emphasize that the GCP can lead to various microeconomic effects through three mechanisms: enhancing enterprise performance, fostering innovation, and upgrading industrial structure [17]. These microeconomic effects contribute towards achieving the goals of energy conservation, emission reduction, and overall environmental quality enhancement. Song et al. [18] indicate that GCP plays a crucial role in supporting green industries by establishing higher loan thresholds and increasing financing costs for polluting industries. The implementation of this policy significantly influences short-term goals, including limiting scale expansion and encouraging investments in technological advancements.

Several scholars have conducted systematic reviews and studies on the factors that impact the high-quality development of enterprises [19, 20]. Their findings reveal that these factors can be categorized into two main types: internal and external influences. The external influence primarily refers to the macroeconomic environment in which the enterprise operates. This macroeconomic environment encompasses various factors, such as government governance [21], fiscal and taxation policies, market structure, market demand, and financial development. Internal influences primarily include firm age, nature of property rights, industrial agglomeration [22], external economic relations [21], and management practices. TFP provides richer and more comprehensive information than intermediate enterprise production and operations variables. Its improvement reflects progress in all aspects of the enterprise, making it a more suitable measure for evaluating high-quality enterprise development. Several scholars have utilized TFP as a proxy variable to examine the effects of innovative city construction [23], the fair competition review system [24], and financial resource allocation [25] on enterprise high-quality development. These studies offer valuable insights for a comprehensive understanding of enterprise high-quality development. Building upon the factors above, this study translates the impact of GCP on enterprises' high-quality development to its effects on enterprises' TFP.

GCP, at its core, represents an environmental policy. However, there is still a lack of consensus among academics regarding the impact of environmental regulation on TFP [26]. Three primary perspectives prevail inhibition, promotion, and uncertainty. According to neoclassical economists, environmental policies are expected to stimulate investments in corporate pollution control, leading to increased production costs and a subsequent decline in TFP [21]. Economists, including Porter, assert that reasonable environmental policies motivate enterprises to adopt positive innovation strategies and adjust resource allocation, ultimately enhancing TFP. This concept, commonly called "Porter's hypothesis" [27], highlights the positive relationship between environmental policy and productivity. Furthermore, scholars argue that the impact of environmental policies on TFP exhibits substantial variation based on regional factors, industries, and the specific ecological regulations in place [28, 29]. Overall, the studies above have primarily focused on the influence of administrative and market-oriented approaches on enterprise TFP, with limited attention given to the impact of credit resource allocation on this measure.

In conclusion, the existing literature provides only limited analysis of the micro-level effects of GCP, and there is a noticeable absence of discussion on whether GCP can effectively drive the green transformation of enterprises. However, there is still no consensus on whether implementing this policy can effectively enhance TFP and foster the high-quality development of enterprises. The existing literature covers a wide range of research samples but lacks studies focused on specific industries. This study focuses on Chinese heavy polluters as the research sample and examines the effects of the policy at the industry level. Regarding empirical research, this study utilizes a difference-in-difference (DID) model, which is well-suited for analyzing policies across various regions and periods.

2.1. GCP and high-quality enterprise development

GCP, serving as a primary instrument in green finance, allows for allocating funds in banks and other financial institutions towards future green projects based on anticipated income over time. In essence, the GCP entails the government's guidance of financial institutions to drive environmental conservation and development through economic influence. Specifically, this entails mandating financial institutions to offer credit support to industries involved in the recycling economy, research, and development, as well as the manufacture of environmental protection equipment, in alignment with the nation's environmental, economic, and industrial policies. Moreover, these institutions are expected to provide preferential measures such as lower interest rates. Meanwhile, they should also enforce restrictions and prohibitions on granting credit to overcapacity and polluting enterprises. GCP aims to efficiently allocate funds by directing them towards environmentally friendly industries while withdrawing financial support from backward industries burdened with pollution and overcapacity.

Regarding the correlation between the GCP and the high-quality development of enterprises, extensive research has been conducted on GCP and enterprise development both domestically and internationally. Efficient resource allocation is crucial for achieving high-quality economic development and industrial upgrading. Extensive literature supports the notion that a well-developed financial system helps mitigate external financing constraints faced by enterprises. Furthermore, it positively impacts TFP by facilitating optimal fund allocation and fostering high-quality enterprise development [30–32]. "Porter's hypothesis" suggests that well-designed environmental regulations can stimulate enterprise innovation and development. By encouraging increased investment in research and development, enterprises can enhance technological capabilities, achieve more efficient and sustainable production processes, improve business performance, and cultivate their core competitiveness [27]. By utilizing the GCP, firms have the chance to secure environmentally friendly loans, leading to a reduction in the debt leverage of highly polluting companies [33–35]. Such an approach enhances green enterprises' risk-taking capacity [36] and contributes to reducing carbon emissions. Furthermore, it fosters the adoption of green innovation and facilitates the shift towards a more sustainable development mode [8].

The GCP reflects the government's intent to intervene at a micro-level and facilitate technological innovation within highly polluting enterprises. This intervention aims to redirect resources from outdated and environmentally harmful production capacities. Doing so compels HPEs to undergo a transformation and upgrade by adopting low-carbon technological innovations [17]. The objective is to shift away from environmentally damaging production methods, enhance the development of core technological innovations, and facilitate the high-quality development of highly polluting enterprises [37, 38]. The mechanism by which GCP influences the high-quality development of heavily polluted enterprises is as follows: commercial banks provide credit support to green and low-carbon projects, encouraging the enhancement of production methods. Consequently, they play a role in stimulating financial support for high-polluting enterprises in environmental governance and carbon emissions management [39, 40]. This facilitates convenient and accessible credit fund availability for enterprises, thereby promoting upgrading their production technology and fostering low-carbon and high-quality development. We propose the following hypotheses:

Hypothesis 1: *The GCP significantly positively impacts the high-quality development of heavily polluting enterprises.*

2.2. Mechanisms by which GCP affects high-quality enterprise development

China is currently in a phase of high-quality development, making it imperative to actively pursue the development of a green and low-carbon economy. This endeavor is a requirement dictated by the current era and a crucial aspect of the transformative process. Technological innovation plays a pivotal role in supporting the green transformation of enterprises and achieving high-quality development. The implementation of GCP has significantly impacted the competitive landscape, placing survival pressure on enterprises and compelling them to engage in low-carbon technological innovation [41]. Low-carbon technological progress improves enterprises' production technology and enhances resource allocation efficiency, which enables enterprises to simultaneously achieve energy savings, emissions reduction, and improved economic efficiency, thereby promoting high-quality development [42, 43].

The green financial system, exemplified by GCP, robustly supports enterprises in integrating green performance and financial performance. Furthermore, investors in the market are increasingly recognizing the significance of environmental performance for enterprises. Consequently, enterprises are compelled to proactively embrace the prevailing low-carbon technological innovation to secure their survival and enhance competitiveness in the evolving competitive landscape [29]. The GCP is crucial in promoting enterprise development by reducing financing costs, enhancing investment efficiency, providing significant financial support for low-carbon technology development, and increasing the output of green innovation for enterprises [44–46]. Porter's hypothesis posits that environmental regulations incentivize enterprises to proactively adopt and improve low-carbon production technologies, thereby creating an "innovation compensation" effect [16]. This effect arises from the higher costs incurred by enterprises falling under the restricted phase-out category, including pollution treatment costs and credit costs, which outweigh the investments in technology inputs. Effective environmental protection policies can incentivize enterprises to innovate, thereby improving their competitiveness and, to some extent, mitigating the cost increases resulting from ecological regulations [47].

The essence of the "Porter effect" in GCP lies in altering the loan threshold, thereby imposing financing constraints on traditional pollution-intensive projects undertaken by enterprises [48]. Enterprises are encouraged to engage in environmentally friendly technological innovation, ultimately facilitating green transformation [49, 50]. Enterprises are motivated to engage in environmentally friendly technological innovation, thereby enabling the realization of green transformation [51] and fostering the high-quality development of enterprises.

Low-carbon technological progress can offer enterprises competitive advantages such as green and low-carbon products, high technical content, and strong uniqueness. Furthermore, low-carbon technological innovation in heavily polluted enterprises can propel them to achieve a qualitative leap in terms of the quality and efficiency of their development. Enterprises can improve their performance and productivity by employing environmentally friendly resources and enhancing input-output efficiency. The low-carbon technological innovation of HPEs has the potential to significantly improve the quality and efficiency of enterprise development [52]. It enables the scientific utilization of environmental resources and enhances input-output efficiency. The low-carbon technological innovation of enterprises plays a moderating role in the influence of GCP on their high-quality development. As the level of low-carbon technological progress increases, the positive effect of GCP on the high-quality development of enterprises becomes stronger. Then, we put forward the following hypotheses:

Hypothesis 2: *As low-carbon technological progress increases, the positive effect of GCP on the high quality of enterprise development becomes stronger.*

3. Methodology and Analysis

3.1. Data

3.1.1. Industry segmentation

This study explores the impact of GCP on HPEs as its primary research focus [53]. The high-pollution and high-energy-consuming industries, referred to as the top ten industries, are *determined* based on their energy consumption levels within the industry. These industries encompass coal mining, oil and gas extraction, textile industry, paper, and paper products industry, petroleum processing and coking industry [54], chemical raw materials and products manufacturing industry, non-metallic mineral products industry, ferrous metal smelting and calendaring processing industry, non-ferrous metal smelting and calendaring processing industry, as well as electric power steam and hot water production and supply industry [4, 55].

For this study, data from the listed companies of Lushan A-share from 2005 to 2022 were chosen as the original samples. To ensure data validity, the following samples were excluded: (1) enterprises categorized as ST and *ST; (2) enterprises with substantial missing values; (3) financial enterprises; and (4) enterprises with a balance sheet ratio greater than 1. Ultimately, data from 2,168 listed companies were included, resulting in 20,585 observations. Among these, 5,146 were classified as heavy polluters, while 15,439 were classified as non-heavy polluters. We obtained the data from the Cathay Pacific database, the China Industrial Enterprise Pollution Database, and the China Statistical Yearbook.

The so-called high-quality development pays more attention to improving the quality and efficiency of enterprises and to the process and results of the influence of internal and external factors on enterprises [56, 57]. For the high-quality development of enterprises, the progress of technology, management, and other aspects is particularly important. TFP is a key proxy variable to measure the structure of China's new era of economic development of enterprises as well as the quality standards [58]. TFP can significantly reflect the high-quality and sustainable development of an enterprise. The "14th Five-Year Plan" and the Vision 2035 Outline especially emphasize the in-depth implementation of the green manufacturing project and the promotion of high-quality development of the manufacturing industry. Therefore, this study chooses the TFP reference as the measurement index.

This study applies the LP method to measure the TFP. Then, we set the following enterprise production function:

$$Y_{it} = A_{it} L_{it}^{\alpha} K_{it}^{\beta} M_{it}^{\gamma} \tag{1}$$

where Y_{it} represents the real value added of the representative firm, measured by the total profit of the heavy polluting firm, L_{it} represents the employment size of the firm, measured by the number of people employed by the heavy polluting firm, K_{it} represents the real capital of the firm, measured by the value of fixed assets currently owned by the heavy polluting firm, respectively; M_{it} represents the intermediate inputs, measured by the products purchased by the heavy polluting firm in the course of its normal energy use, the services it enjoys A_{it} is TFP. Applying the natural logarithm to Equation (1) converts it into the linear form as follows [59]:

$$y_{it} = \alpha l_{it} + \beta k_{it} + \gamma m_{it} + \mu_{it} \tag{2}$$

where y_{it}, $l_{it,}$ k_{it}, and m_{it} denote the logarithmic forms of Y_{it}, $L_{it,}$ K_{it}, and M_{it} respectively. The residual term of Equation (2) contains information on the logarithmic form of the firm's TFP (A_{it}). Equation (2) provides a TFP estimate. We sourced the data from the Cathay Pacific and Wind databases.

3.1.2. GCP

The HPEs are the primary focus of the policy. We categorize listed companies in this sector as the experimental group and those in the non-HPEs (non-HPEs) as the control group [60]. Heavily polluted enterprises observed in 2012 and later are assigned a value of 1, whereas those before 2012 are assigned a value of 0.

3.1.3. Low-carbon technological progress

Technological innovation refers to the creation of new technologies or advancements based on scientific and technical knowledge and resources at its disposal. The patents held by enterprises can serve as a gauge of the extent of their technological innovation. In contrast, low-carbon technology patents are more representative of the degree of low-carbon technological progress, and we can use low-carbon technology innovation indicators based on the number of patents to measure the degree of activity of low-carbon technology research in the macroeconomy [61, 62]. Therefore, according to the identification results of the 2009 research project on low-carbon patent classification by the United Nations Environment Program and the International Center for Trade and Sustainable Development, the European Patent Office and the U.S. Patent Office jointly constructed the Combined Patent Classification [63]. We measure low-carbon technology progress by the number of patents in the Joint Patent Classification [64].

3.1.4. Socio-economic data

Socio-economic variables are non-core explanatory variables that significantly impact the explained variables [65]. As the control variables in this study, the specific indicators and measurements are shown in Table 1. Table 2 shows the descriptive statistics of the main variables.

3.2. Methodology

This study leverages the GCP as a quasi-natural experiment to examine its impact on the high-quality development of enterprises. Following Guo and Zhang [2], we establish a two-way fixed-effects model by applying the DID approach:

$$Tfp_{i,t} = \beta_0 + \beta_1 GCP_{i,t} + \gamma Control_{i,t} + \sum year + \sum Ind + \varepsilon_{i,t} \tag{3}$$

where $Tfp_{i,t}$ is the TFP of enterprise i in period t, $GCP_{i,t}$ is a policy dummy variable, which takes the value of 1 if the enterprise in 2012 [66] and later belongs to a highly polluting industry, and 0 otherwise;

Table 1
Symbols and definitions of major variables

Type	Name	Code	Definition
Dependent variable	TFP of heavy polluting enterprise	*TFP*	Total factor productivity under the LP method
Regulated variable	Low-carbon technology progress	*LCTP*	0 Heavy polluting enterprises before 2012, and 1 otherwise The sum of the number of patent applicants for Y02B, Y02C, Y02P, Y02T, and Y02W in the Y02; series under the Combined Patent Classification Low-Carbon Technology Classification is taken as a logarithm
Control variables	Internal control level enterprise size	*Bic*	Internal control index
	Proportion of fixed assets	*Size*	Enterprise Value Multiplier fixed assets /Total assets
	Growth opportunity	*Fix*	(Equity market value+Net debt market value)/Total assets
	Check and balance the ownership structure	*TobinQ*	Capital per share/General Capital
		Balance	Number of shares held by the largest shareholder/General Capital
	Ownership concentration Profitability Growth Enterprise maturity	*Top*	(Total profit+ Total expense)/Average total assets
		ROA	(Operating income for current year operating Income for the same period of the previous year) / (operating income for the same period of the previous year)
		Growth	
		Firm Age	Year of business establishment
Robustness test variables	Green TFP	*GTFP*	Total factor productivity under the SBM-ML index method

Table 2
Descriptive statistics

Variable	Obs	Mean	S.D.	Min	Max
TFP	5148	8.16	1.05	4.89	12.15
BIC	5148	664.64	116.50	0.00	977.7
Growth	5148	0.19	0.45	−0.74	4.81
TobinQ	5148	1.90	1.29	0.82	17.68
FirmAge	5148	2.74	0.42	1.10	3.56
Top	5148	0.35	0.15	0.08	0.76
Balance	5148	0.59	0.55	0.01	2.80
Size	5148	21.97	1.26	19.24	26.40
Roa	5148	0.04	0.06	−0.41	0.24
Fix	5148	0.45	0.21	0.00	0.98

The coefficient of interest is $\beta1$, which indicates the net effect of GCP on the development of high-quality of HPEs. $Control_{i,t}$ is a set of control variables, $\sum year$ denotes the year fixed effect; $\sum Ind$ denotes the industry fixed effect; $\varepsilon_{i,t}$ denotes the error term.

4. Empirical Results

4.1. Benchmarking results

Table 3 presents the results of the benchmark regression analysis. According to the results presented in Column (1) of Table 3, when no control variables were included, the coefficient of GCP is estimated to be 0.0911 and passes the significance test at the 5% level. The result indicates a positive impact of the GCP on the high-quality development of HPEs. Even after controlling for socio-economic effects, the estimate of GCP remains significantly positive (Column (2)). Our finding demonstrates that the theoretical analysis regarding the impact of GCP on TFP has been effectively validated through empirical research.

4.2. Parallel trend test

The underlying assumption of the DID method is that the treatment and control groups adhere to the parallel trend assumption [67, 68], which implies that there are no significant differences in the changes of TFP between the treatment and control groups before the implementation of the policy intervention. Following Jacobson et al. [69], we perform a parallel trend test using Equation (4):

Table 3
Results of DID

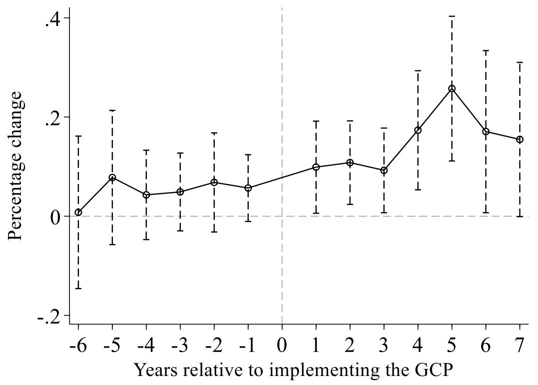
	LnTFP	
Variables	(1)	(2)
GCP	0.0911**	0.0908**
	(0.0460)	(0.0460)
Control		√
Ind FE	√	√
Year FE	√	√
City* Year	√	√
Con	11.7210***	9.5477
	(0.8557)	(10.4183)
Observations	5148	5148
R-squared	0.346	0.346

Note: ***, **, and * indicate significance at 1%, 5%, and 10%, respectively. The values in brackets represent standard errors.

$$y_{i,t} = \beta_0 + \prod_{s\geq -5}^{5} \beta_s GCP_s + \beta_2 Control_{i,t} + \sum year + \sum Ind + \varepsilon_{i,t} \tag{4}$$

where GCP_0 denotes the dummy variable for the year of implementation of the GCP (2012), s, when negative, denotes s years before the promulgation of the GCP, and s, when positive, denotes s years after the promulgation of the GCP. We exclude the GCP implementation year, thereby estimating its dynamic impact on TFP in relation to this milestone. The results are shown in Figure 1. Prior to the introduction of the GCP, there was no observable variation in the TFP of enterprises across different years. The observation supports the assumption of a DID parallel trend. However, following the implementation of the GCP, a notable shift

Figure 1
Parallel trend test



Notes: The horizontal axis represents the time span before and after the enactment of the GCP. The black dots represent the estimates, with the dashed lines indicating 95% confidence intervals.

in TFP between HPEs and non-HPEs is observed. The finding further suggests that the adoption of the GCP plays a significant role in promoting the high-quality development of enterprises.

4.3. Robustness checks

4.3.1. PSM-DID

To address the variations in the implementation of GCP documents and mitigate potential estimation biases inherent in the DID approach, we employ the propensity score matching (PSM) method in conjunction with the DID estimator to analyze the impact of GCP [2]. Specifically, we employ the PSM method to mitigate the influence of confounding variables and ensure comparability between the treatment and control groups, which involves matching the industries in the treatment group with those in the control group based on their identification features [63]. Then, we perform regression analysis using the matched data to examine the effects of interest. The regression results of the PSM-DID model indicate (Column (1), Table 4) that the GCP continues to promote the high-quality development of enterprises. The conclusions drawn in this study remain robust.

Table 4
Robustness check results

Variables	(1) PSM-DID	(2) Shorten the time window	(3) Counter fact check
		LnTFP	
GCP	0.0958**	0.0402*	0.0883
	(0.0467)	(0.0234)	(0.0629)
Control	√	√	√
Ind FE	√	√	√
Year FE	√	√	√
City* Year	√	√	√
Con	8.7823	5.8173	9.4454
	(10.4514)	(8.5541)	(10.3597)
Observations	4998	3136	5046
R-squared	0.349	0.128	0.355

4.3.2. Additional robustness checks

1) Shorten the time window. This study modifies the time window for conducting a robustness test to mitigate the potential impact of other events preceding and following the introduction of GCP on the estimates. The data from three years (2009–2015), before and after the implementation of GCP, are selected as the research timeframe for a robustness test. The estimate in Column (2) of Table 4 reveals a significantly positive effect of the GCP, aligning with the empirical findings in the preceding section.
2) Counterfactual test. The period before the introduction of GCP is selected as the study period (2005–2012), and the time dummy variable Year 2010 is set, which takes 1 in 2010 and 0 otherwise. Column (3) of Table 4 reveals that the estimates associated with the GCP are all statistically insignificant. Prior to the implementation of the GCP, there was no significant alteration in the TFP of heavy polluters compared to non-heavy polluters. Consequently, there are no notable changes in the overall measure of productivity.

4.3.3. Placebo test

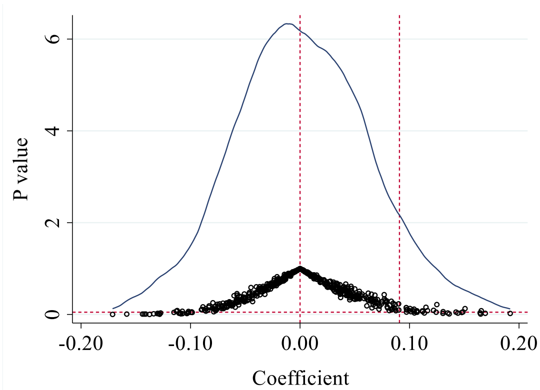
The potential presence of omitted firm-time-level variables is another factor that could result in biased estimation results [70]. Specifically, unobservable characteristics of enterprises that may change over time could influence the estimation of the net effect of the GCP in this study. A placebo test randomly assigns treatment and control groups to address this concern [71, 72]:

$$\widehat{\beta}_1 = \beta_1 + \lambda \frac{cov\left(GCP_{i,t}, \varepsilon_{i,t} \mid Control \right)}{cov\left(GCP_{i,t} \mid Control \right)} \tag{5}$$

where Control denotes the control variable, and if $\lambda = 0$, it means that the β_1 estimation result is unbiased. However, it is not possible to directly test whether λ is 0. If a certain variable can be used to replace $GCP_{i,t}$, and it does not have a substantial effect on the explanatory variables (i.e., $\beta_1 = 0$), in this case, if it can still be measured $\beta_1 = 0$, then it can be inverted to $\lambda = 0$.

To enhance the precision of the placebo test, this study employs the bootstrap method and conducts 1000 iterations of the randomization process. The outcomes are depicted in Figure 2. As

Figure 2
Placebo test



Notes: The graph displays the coefficient distribution of 1000 virtual policies. The curve represents the kernel density distribution of the estimates, with the black dot denoting the p-value. The vertical dashed line represents the "real" estimate (0.0908), while the horizontal dashed line indicates a significance level of 0.05.

evident from Figure 2, the estimated values are clustered around zero, with a majority of the *p*-values being greater than 0.1. Notably, the true estimates, represented by the vertical lines, stand out as clear outliers in the placebo test. The results demonstrate that the effect of the GCP remains unaffected by the presence of unobserved omitted variables.

5. Discussion

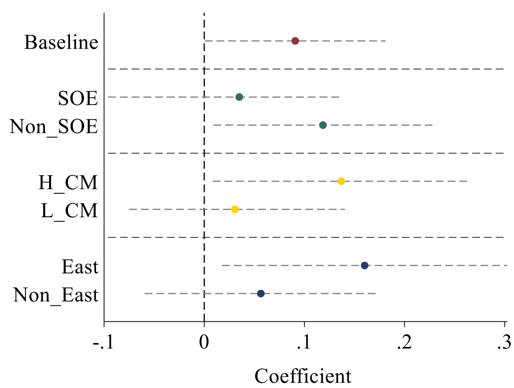
Previous research provides empirical evidence for the theoretical analysis, thereby confirming the significant impact of GCP in facilitating the high-quality development of enterprises [73]. However, it remains to be seen whether there are variations in the responses of diverse enterprise types to this policy. To determine which enterprises are most affected by the GCP in terms of TFP, we examine the varied impacts of GCP on the high-quality development of enterprises. This analysis considers factors within the internal environment, such as the nature of property rights and carbon emissions, and factors within the external environment, such as geographical disparities.

5.1. Heterogeneity analysis

5.1.1. Heterogeneous effects across the perspective of enterprise ownership

In the credit market, state-owned enterprises (SOE) benefit from distinct financing advantages, whereas non-state-owned enterprises (Non_SOE) experience varying levels of "ownership discrimination". Hence, the effects of GCP at the micro-level may vary depending on the ownership structure of enterprises [2]. The findings in Figure 3 reveal that GCP is more significant in the sample of non-state-owned firms, which suggests that GCP has a stronger role in promoting the high-quality development of Non_SOE than SOE. Implementing the GCP helps alleviate the capital scarcity faced by Non_SOE, ensuring sufficient funds for management, innovation, and transformation, thereby fostering the high-quality development of domestic Non_SOEs. Nevertheless, SOEs have adequate access to external financing and are less responsive to the influence of GCP.

Figure 3
Heterogeneity analysis



Notes: The figure presents the heterogeneity of GCP across various enterprise ownerships, carbon emissions, and locations; the first row serves as the baseline for comparison; each dot represents the estimates, and gray lines represent 95% confidence intervals.

5.1.2. Heterogeneous effects across the perspective of enterprise carbon emissions

Green finance can potentially drive the upgrading of industrial structures and optimize energy consumption. The process of upgrading industrial structures aligns closely with the intention to achieve "carbon neutrality" and emphasizes resource conservation and environmentally friendly allocation. Consequently, enterprises with varying levels of carbon emissions may experience divergent micro-level effects from implementing GCP.

Figure 3 indicates that the impact of the GCP is more pronounced in the subset of firms with higher carbon emissions (H_CM), implying that GCP plays a more influential role in promoting the high-quality development of firms with H_CM than those with lower carbon emissions (L_CM). GCP provides financial support to enterprises with high carbon emissions and significant pollution but also exhibits potential for transformation, which is accomplished by providing diverse financial services, ultimately facilitating the gradual transition of the industrial structure towards a modern economic framework emphasizing green technology. Additionally, GCP serves as an incentive for enterprises to adopt low-carbon and environmentally friendly production methods. On the other hand, enterprises with low-carbon emissions demonstrate a relatively rational and optimal resource allocation, emphasizing environmental sustainability.

5.1.3. Heterogeneous effects across the perspective of location

To compare the impact of the GCP on TFP across different locations, we divided the sample into the East and Non-Eastern groups [74]. Figure 3 demonstrates that GCP plays a more robust role in promoting the high-quality development of firms in the eastern region (East) compared to the Non-eastern regions (Non-East). The institutional environment in the eastern region is relatively well-established compared to the Non-eastern regions. The concept of green finance is deeply ingrained in the mindset of the people [75], and both the local government and enterprises place significant emphasis on environmental pollution control. In contrast, enterprises in the western region prioritize economic efficiency over environmental pollution control due to their developmental needs, which impedes their ability to respond effectively to the GCP in non-eastern regions.

5.2. Mechanism analysis

5.2.1. Decomposition effect of GCP on enterprise high-quality development

We examine the positive impact of the GCP on enterprises' high-quality development and explore its decomposing effect. The decomposition of TFP replacement involves changes in technical efficiency and technological progress. *EFFCH* represents the technical efficiency index. A value greater than 1 signifies improved green technology efficiency, while less than 1 indicates deterioration. The technical progress index, defined by *TECH*, serves as an indicator of green technology advancement. A value greater than 1 indicates progress in green technology, while a value less than 1 suggests regression. Hence, this study utilizes the two decompositions above indices as dependent variables and incorporates them into Equation (3) for regression analysis. The relevant decomposition results are presented in Table 5.

The estimation results utilizing *EFFCH* and *TECH* as dependent variables are presented in Columns (1) and (2) of Table 5. Both estimates show a notable positive correlation between GCP, technical efficiency, and technological advancement. The policy incentivizes a combination of technological progress and technical

Table 5
Decomposition effect

Variables	(1) *EFFCH*	(2) *TECH*
GCP	0.0018*	0.0043**
	(0.0010)	(0.0020)
Control	√	√
Ind FE	√	√
Year FE	√	√
City* Year	√	√
Con	0.7399***	1.0105***
	(0.0191)	(0.0309)
Observations	3281	3393
R-squared	0.981	0.003

Table 6
Regulatory effect

Variables	(1) *LnTFP*	(2) *Lctp*	(3) *LnTFP*
GCP	0.0908**	0.0284**	0.0824**
	(0.0460)	(0.0132)	(0.0379)
GCP × *Lctp*			0.0594**
			(0.0231)
Control	√	√	√
Ind FE	√	√	√
Year FE	√	√	√
City* Year	√	√	√
Con	9.5477	−0.0333	5.6014
	(10.4183)	(3.1928)	(11.9871)
Observations	5148	5148	5148
R-squared	0.346	0.023	0.221

efficiency, resulting in an improvement in firms' TFP. Upon acquiring green credit funds, enterprises allocate these resources towards green innovation and technological upgrades to offset production cost losses. The analysis above collectively highlights the crucial role of technological innovation in the impact of GCP on the high-quality development of enterprises.

5.2.2. Derating effect of low-carbon technological progress in the effect of GCP

The preceding section confirmed that technological innovation is pivotal in the impact of GCP on promoting enterprises' high-quality development [76]. During the high-quality development of heavily polluted enterprises, advancements in low-carbon technology can provide these enterprises with competitive advantages such as producing green and low-carbon products, greater technological sophistication, and enhanced non-substitutability. To achieve a low-carbon green transformation, enterprises enhance their low-carbon technological progress. However, if they fail to allocate funds towards the research and development of new technologies [41], their TFP will not display growth. The low-carbon technological innovation of enterprises within the framework of the GCP exerts a moderating effect on their high-quality development. Specifically, as low-carbon technological progress increases, the positive impact of GCP on enterprises' high-quality development becomes stronger. The low-carbon technological progress of enterprises has a moderating effect on the impact of GCP on their high-quality development [28]. This relationship will be examined and verified in the upcoming section.

The primary objective of this study is to empirically examine the heterogeneous micro effects of GCP based on the level of low-carbon technological progress. We adopt the median level of low-carbon technological progress as the criterion for grouping firms. If a firm surpasses the median level, it is assigned a value of 1 for *Lctp*; otherwise, it is 0 [6]. The empirical findings are presented in Table 6. According to the findings in Column (1), the estimate for the GCP is 0.0908 and exhibits statistical significance at the 5% level. The result indicates that the GCP effectively promotes enterprises' high-quality development, thus supporting Hypothesis 1. The estimate in Column (2) reveals that the low-carbon technological progress of the enterprise, used as an explanatory variable, has an estimate of 0.0284 for the GCP. This finding demonstrates that the GCP effectively promotes the high-quality development of enterprises. Additionally, as indicated in Column (3), when incorporating the regression of the interaction term of low-carbon technology progress *GCP* × *Lctp*, the estimate of the cross term is 0.0594, which demonstrates statistical significance at the 1% level. The empirical data supports Hypothesis 2 of this study, which suggests that low-carbon technological progress moderates the impact of GCP on high-quality enterprise development. The findings indicate that as the level of low-carbon technological progress increases, the positive effect of GCP on high-quality development strengthens. We have effectively validated Hypothesis 2 through empirical research.

6. Conclusions and Future Works

6.1. Conclusions

Using panel data from listed companies in the Shanghai and Shenzhen stock exchanges between 2005 and 2022, this study examines the impact of the GCP on the high-quality development of HPEs. The result shows that: (1) The GCP is conducive to promoting the high-quality development of enterprises, and this positive effect is particularly pronounced among Non_SOE, characterized by high carbon emissions, and in the eastern region. (2) The mechanism analysis indicates that GCP plays a role in influencing the high-quality development of enterprises by promoting low-carbon technological progress.

6.2. Future works

Based on the empirical findings, this study proposes the following suggestions: First, the government is encouraged to enhance the exploration and development of GCP. We can achieve the goal by establishing a robust mandatory disclosure system for environmental information, promoting positive incentives for low-carbon investment and financing, and ensuring the effective allocation of green resources. Second, when formulating GCP, government departments should thoroughly consider the diverse backgrounds of enterprises and implement targeted and practical measures. For instance, in developing a performance evaluation index system for HPEs, it is essential to consider their ownership structure and size. Third, to truly harness the guiding, incentivizing, and supervisory roles of GCP, it is essential to establish a standardized system for evaluating the impacts of its implementation. This system should comprehensively assess policy effectiveness and identify key obstacles. Fourth, the government should actively provide policy support for cutting-edge science, technology, and green low-carbon technologies in key areas of heavy polluting enterprises.

The results of this paper suggest several areas for further research. An unresolved pivotal issue lies in the effective integration of additional negative externalities outputs like wastewater, exhaust gases, and solid waste to enhance the precision of TFP calculation. The key challenge is how to precisely evaluate the high-quality development indicators of HPEs from a micro-level perspective and integrate them into financial institutions' environmental investment and financing strategies. Furthermore, this study has verified that green credit is a crucial bridge connecting financial resources and the ecological environment, enabling high-quality development for HPEs. So, how can we ensure the improvement of the GCP system, thereby continuously stimulating the transformation dynamics of enterprises? These aspects could serve as potential avenues for future research endeavors.

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Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

Author Contribution Statement

Lili Xu: Conceptualization, Methodology, Software, Formal analysis, Writing – review & editing, Visualization, Project administration. **Chang Li:** Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft. **Xinxin Zhang:** Conceptualization, Resources, Writing – review & editing, Supervision, Funding acquisition. **Xu Zhao:** Conceptualization, Resources, Writing – review & editing, Supervision, Funding acquisition.

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