



Green finance policies, financing constraints and corporate ESG performance: insights from supply chain management

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Abstract

Green finance represents an innovative policy framework aimed at fostering corporate engagement in ESG practices. Drawing on data from Chinese A-share listed companies between 2007 and 2021, this study leverages the 2016 "Guiding Opinions on Building a Green Financial System" as a quasi-experimental setting. By employing a continuous double-difference model, we rigorously investigate the influence of green finance policies (GFP) on corporate ESG performance and elucidate the underlying mechanisms. The findings demonstrate a substantial improvement in corporate ESG outcomes attributable to GFP; however, this effect exhibits variability, influenced by the extent of corporate supply chain finance and the transparency of supply chain operations. Detailed mechanism analysis reveals that GFP impacts ESG performance through the reinforcement of external financing constraints, enhancement of internal supply chain efficiency, and reduction of managerial power. Heterogeneity analysis highlights differential impacts on firms based on regional characteristics, particularly in areas with high urban innovation, stringent environmental regulations, and advanced supply chain digitization. Therefore, refining the GFP framework is imperative, emphasizing the understanding of corporate behavior in shaping policy effectiveness, ultimately steering companies toward sustainable development. This study contributes to the theoretical discourse on GFP and their implications for corporate ESG performance, while providing actionable insights for policy optimization.

Keywords Green finance policy · ESG performance · Supply chain · Managerial power · Green innovation

Abbreviations

GFP	Green Finance Policy
ESG	Environmental, social and governance
GF	Green finance
SC	Supply chain
SD	Sustainable development
ER	Environmental regulation
FC	Financing Constraints

1 Introduction

Against the backdrop of global climate change and environmental concerns (Fried 2022; Sautner et al. 2023), the Chinese government has set an ambitious target at the UN General Assembly to achieve peak carbon by 2030 and carbon neutrality by 2060. This 'dual carbon' goal has become an important strategic decision to drive the structural transformation of the country's economy (Chen et al. 2023). This decision reflects China's commitment to building a more sustainable future as it moves into a new economic era. Green finance (GF) is at the heart of this strategy as an important policy innovation aimed at encouraging firms to actively participate in environmental governance and promoting economic development and structural adjustment (Stroebel and Wurgler 2021). The Guiding Opinions on Building a Green Financial System, issued in 2016, is considered a significant milestone in promoting GF in China, demonstrating the country's dedication to this cause. The guidance promotes the development of GF, the promotion of green and low-carbon financial products and services, and the establishment of a sound green financial standard system. This has become a

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key factor in promoting green and sustainable development (SD). Our study raises a fundamental question: can green finance policy (GFP) effectively enhance ESG performance? Our study takes a supply chain (SC) perspective to examine the intricate dynamics that GF initiatives create for corporate practices. The aim is to contribute to the broader discussion of sustainable economic practices and inform policymakers, businesses, and academics about the potential effectiveness of GFP in achieving the 'dual carbon' goal of promoting green and SD.

GFP constitutes a series of measures intended to enhance corporate involvement in environmental governance and SD. These measures include financial support, incentive mechanisms, and regulatory frameworks. The scope of GFP includes financial instruments such as green bonds and green loans, alongside mandatory transparency in information disclosure and standardized assessment systems. The objective of these policies is to elevate corporate environmental and social responsibility, thereby facilitating the transition to a greener economy and promoting SD. In the current global environmental sustainability agenda, GFP have emerged as an important driver in shaping corporate sustainability (McBrayer 2018; Azar et al. 2021). Firms in this framework aim to achieve considerable ESG performance through environmentally and socially responsible practices, as well as good corporate governance, underpinned by the development of a forward-looking green financial system. Previous research has highlighted the significance of this field (Pedersen et al. 2021; Cai et al. 2014; Thomas et al. 2022). Additionally, Zhang et al. (2011) have suggested that GFP can play a crucial role in reducing credit rationing in the 'two high' industries and guiding enterprises to adjust their development strategies and achieve their industrial structure. By reducing credit allocation to industries with excessive emissions, enterprises can adjust their development strategies and optimize their industrial structure. This can have a positive effect on promoting green and SD as well as environmental governance (Krueger et al. 2020; Chen et al. 2023; Le et al. 2024). Enterprises play a crucial role in promoting green transformation as one of the main bodies of GF. Their contribution is essential to improving ESG performance (Schäfer et al. 2023; Huarng and Yu 2024). The ESG system has provided a new development framework for enterprises, emphasizing their broader social responsibility in investment and operation. Within this framework, firms' economic resources have become a key factor influencing ESG performance (Colonnelli et al. 2023; Jiang et al. 2023). Previous research has demonstrated a correlation between a company's motivations for green transformation and the degree to which they adjust their ESG performance in response to changes in economic resources (Chaney et al. 2016; Sun and Gunia 2018; Barratt and Oke 2007; Avramov et al. 2022). However, there is a lack of research on the precise impact of GFP on firms' ESG

performance. This study aims to address this gap, specifically focusing on the relationship between SC transparency, SC finance, and ESG performance. Previous studies by Pástor et al. (2021), Wang and Cai (2023) and Hamdy (2024) have touched on this topic, but have not explored it in depth. Additionally, Inderfurth et al. (2013), Li et al. (2020), and Cui et al. (2023) have examined the relationship between SC transparency and SC finance, but have not considered the impact on ESG performance. Therefore, this study aims to contribute to the existing literature by exploring this unique perspective. The aim of this study is to investigate the impact of GFP on corporate ESG performance through empirical research. Additionally, we aim to identify the internal and external mechanisms for implementing these policies.

In light of escalating global climate change and environmental challenges, GFP have emerged as a crucial strategy for fostering SD. The Chinese government's pledge to achieve peak carbon emissions by 2030 and attain carbon neutrality by 2060 highlights the need for effective financial mechanisms to support this transition. Despite the considerable attention GFP has received, there is still a lack of comprehensive understanding of its impact on corporate ESG performance, especially from a SC perspective. This study addresses this gap by investigating how GFP influences corporate ESG performance, with a particular focus on the roles of SC finance, SC transparency, and capital use efficiency in moderating GFP's effectiveness. Utilizing data from Chinese A-share listed companies spanning 2007 to 2021, this research employs a continuous double-difference model to provide robust empirical evidence on the mechanisms through which GFP impacts corporate practices. Understanding these dynamics is essential for policymakers, businesses, and academics to devise and implement more effective GFP. This study aims to contribute to the broader discourse on sustainable economic practices by emphasizing the heterogeneous effects of GFP across different corporate contexts. Ultimately, it seeks to provide actionable insights that can guide companies towards achieving green and SD, in alignment with China's strategic environmental goals.

Previous research has not given sufficient consideration to the effect of GFP on corporate ESG performance (Williams et al. 2013; Huo et al. 2021; Starks 2023; Lei and Yu 2023; Xu et al. 2024). Additionally, the measures of ESG performance provided in past studies have been relatively simplistic (Engle et al. 2020; Lewellyn and Muller-Kahle 2023). This study broadens the research perspective on the micro effects of GFP by taking the perspective of corporate ESG performance behaviour. It also strengthens the focus on corporate ESG performance and its structural changes, providing a more comprehensive analysis of the impact of GFP. Secondly, this study expands the channels through which GFP affect corporate behavioural choices by theoretically decomposing external financing constraints (FC) into the financing cost effect

and financing channel effect (Mithas et al. 2022; Cao et al. 2023; Ronchini et al. 2024). The financing channel effect is quantified by measuring the number of years in which the new loan is zero, as suggested by Houston and Shan (2022). This study argues that firms listed or above-scale may not necessarily face FC. Therefore, it is important to investigate the inhibition of GFP on enhancing internal SC efficiency and curbing managerial power as a significant mechanism (Ha-Brookshire 2017; Welch and Yoon 2023; Asif et al. 2023). Finally, the existing literature finds it difficult to portray firms' behavioural choices under GFP when analysing firms' policy responses (Flammer 2021; Zhu et al. 2023). This study examines three policy responses that firms may adopt from a micro perspective: SC finance, improving SC transparency, and capital use efficiency (Wolf 2014; Sodhi and Tang 2019; Chod et al. 2020; Jafarnejad et al. 2024). The aim is to explore the impacts of firms' behaviours on the policy effects and provide a more profound understanding.

2 Theoretical analysis

2.1 Policy background

With the growing prominence of global environmental issues, GF has become a crucial element in promoting SD. The Chinese Government has taken a significant step forward in this area, demonstrating its strong commitment to environmental protection and SD through the issuance of the Guiding Opinions on Building a Green Financial System. The policy aims to transform and upgrade the economy and achieve SD through the development of GF. The government is committed to increasing support for green financial products and encouraging financial institutions to issue green bonds, green loans and other financial instruments to promote financing and investment in green industries. This initiative aims to broaden the financing options available to environmentally friendly enterprises and projects, enhance the appeal and profitability of green investments, and offer dependable financial backing for SD (Hong et al. 2020).

2.2 Green finance policy and corporate ESG performance

According to resource dependence theory, GFP alter firms' demand for and supply of finance, leading them to pay greater attention to ESG factors to adapt to the evolving financial landscape while reducing their dependence on environmental and social factors (Hitt et al. 2016; Jiang et al. 2023). According to CSR theory, GFP incentivise firms to fulfil their social responsibilities by focusing on ESG performance, leading to more sustainable operations (Lei and Yu 2023). These policies offer economic incentives, such as

tax breaks, subsidies, and favourable loan rates, to encourage firms to improve their ESG performance (Wolf 2014). These incentives can reduce the cost burden on enterprises, making environmental protection projects more attractive. This, in turn, makes it easier for enterprises to finance and invest in environmental innovation, energy-saving, emission reduction, and social welfare, ultimately leading to superior ESG performance (Krueger et al. 2020). GFP advocate for the establishment of a comprehensive ESG information disclosure and assessment system to improve transparency and standardisation. This will provide investors and financial institutions with more accurate and objective ESG assessment results, and motivate companies to comprehensively improve their ESG performance to seek more financial support (Schäfer et al. 2023). As the demand for sustainable and environmentally friendly products grows, firms are being pushed by GFP to meet market demands and consumer preferences. Improved ESG performance can help firms develop a positive brand image and attract more consumers to environmentally and socially responsible products and services (Brandon et al. 2022). This market driver further incentivises firms to improve ESG performance by increasing market share, sales, and profitability (Bauer et al. 2021).

GFP aim to regulate the environment and allocate financial resources. They increase firms' access to credit facilities (Marron and Toder 2014), and those more affected by them may benefit from government incentives, such as tax reductions, loan concessions, or subsidies, to improve their ESG performance (McBrayer 2018). They increase firms' access to credit facilities (Marron and Toder 2014), and those more affected by them may benefit from government incentives, such as tax reductions, loan concessions, or subsidies, to improve their ESG performance (McBrayer 2018). Furthermore, the implied value of firms is affected by their ESG performance, and GFP are increasing social attention to firms' ESG performance. This makes it crucial for firms to enhance their ESG performance to safeguard their reputation and mitigate potential risks (Ouazad and Kahn 2022). In the context of the SC, firms that are more impacted by GF create a diffusion effect by establishing closer ties with environmentally relevant SC firms. This consequently enhances ESG performance throughout the supply chain. Therefore, this study posits the following hypotheses:

Hypothesis 1: GFP can incentivise firms to improve their ESG performance.

2.3 Levels of supply chain finance, supply chain transparency and regulatory mechanisms for the efficient use of funds

According to the financial demand theory, firms with higher levels of SC finance are more likely to obtain loans and

financing support from financial institutions. This is because such firms are able to provide more reliable financial and operational data, which reduces financial institutions' concerns about creditworthiness risk (Cao et al. 2023). However, firms may rely less on additional financial support provided by GFP, resulting in a relatively smaller boost in ESG performance improvement. GFP aim to provide financial support and incentives for environmental protection and SD. However, firms that utilise SC finance often have better access to financial resources due to their stronger financial position, credit history, and access to capital markets. Consequently, these firms may receive less financial support under GFP (Wang and Cai 2023). Secondly, these companies play a crucial role in the SC and have a significant market share or deep SC relationships. This makes it easier for them to encourage all parties in the SC to adopt measures for environmental protection and SD (Ha-Brookshire 2017; Bhawna and Sharma 2024). Therefore, compared to other companies, those with higher levels of SC finance are less likely to have their ESG performance influenced by the SC under GFP.

The New Institutional Economics theory suggests that SC transparency can reduce information asymmetry and increase trust between firms and financial institutions (Inderfurth et al. 2013). Transparent SCs offer accurate and verifiable information on environmental and social performance. This enables financial institutions to better assess the environmental risks and sustainability of firms, and thus increase financial support for firms with transparent SCs (Gualandris et al. 2021; Zhu et al. 2023). Companies that have a high level of transparency are typically more willing to openly and transparently disclose information about their SCs, including environmental and social data and performance (Chod et al. 2020). This disclosure can improve a company's credit and reputation, enhance stakeholders' trust, and provide reliable data and evidence for GFP (Cui et al. 2023). Firms with high levels of transparency are more likely to receive support from GFP and appropriate funding and incentives compared to other firms (Sodhi and Tang 2019; Piao et al. 2024). Additionally, high transparency enables firms to effectively manage and monitor their SCs, as well as promote and coordinate the participation of various links in the SC towards SD. This enables companies to evaluate the environmental and social risks of their SC links more accurately and take necessary steps to address them with their partners. According to Habermann and Fischer (2023), firms with high transparency are more likely to receive policy support under GFP to implement more comprehensive and in-depth green measures to further enhance their ESG performance compared to other firms.

Efficiency in capital use by firms refers to their ability to utilise capital resources in a way that translates more efficiently into output or value. According to the theory of information economics, firms tend to adopt avoidance

behaviour when faced with uncertainty and risk. Highly capital-efficient firms may use their flexibility and innovation to reduce the need for investment under the environmental requirements of GFP, thus avoiding the policies' impact on their operations. Capital structure theory explains the phenomenon that highly capital-efficient firms enjoy a better reputation and ratings in the capital market. By maintaining efficient operations and financial stability, these firms are more likely to be favoured by investors and raise finance at a lower cost (Schäfer et al. 2023). According to Huarng and Yu (2024), under GFP, these firms may be better equipped to meet policy requirements and make environmental investments at a lower cost of capital, thus limiting the policy's impact on improving their ESG performance. According to the capital asset pricing model, investors typically consider efficient firms to be less risky investments. This is because these firms can use capital more efficiently to create value, resulting in relatively high stock prices and lower corporate finance costs (Pástor et al. 2022). GFP may provide easier access to low-cost financing for firms with high capital efficiency to support their environmental projects and programmes. The theory of information economics emphasises the active information gathering and analysis behaviour of firms in the face of incomplete information and uncertainty. Firms with high capital efficiency tend to exhibit proactive behaviour, which enables them to assess potential rewards and risks of environmental investments more accurately. This, in turn, helps them to predict and solve environmental problems and allocate resources more efficiently to achieve their environmental objectives (Barnett et al. 2020; Queiroz et al. 2024). As a result, these firms are better equipped to adapt to the requirements of GFP and achieve better ESG performance.

Hypothesis 2: The impact of GFP on ESG performance exhibits heterogeneity due to variations in supply chain finance, supply chain transparency, and capital use efficiency.

3 Research design

3.1 Sample selection and data sources

For this study, we selected A-share listed companies from 2007 to 2021 as our research sample. The data sources include basic information, financial statements, profit forecasts, and other relevant data obtained from the China Research Data Service Platform, which facilitated the calculation of control variables, financing costs, and other pertinent indicators. During data processing, we excluded ST, PT, and *ST firms, financial and real estate firms, and firms with gearing ratios exceeding 1. Additionally, we removed

firms with significant missing financial data or other critical indicators and applied bilateral trimming to the 1st and 99th percentiles of all control variables to eliminate outliers. Furthermore, we collected industry pollution emissions data from the China Environmental Statistics Yearbook and obtained managerial power data from the CSMAR database and annual reports, matching this data with the listed company data. These steps resulted in a research sample comprising 1,185 listed companies.

3.2 Model construction and variable definition

This study investigates the impact of the 2016 Guidance on Building a Green Financial System, a green financial policy, on corporate ESG performance through a continuous difference-in-differences approach as a quasi-natural experiment. The difference-in-differences model aims to identify the average treatment effect of the policy by comparing the intensity differences between the treatment and control groups under the policy's influence. To test hypothesis 1, the study constructs the following model:

$$ESG_{jt} = \beta_0 + \beta_1 GFP_{jt} + \beta_2 Treat_{jt} + \beta_3 X_{jt} + \lambda_f + \lambda_j + \lambda_p + \lambda_t + \varepsilon_{jft} \quad (1)$$

The model above uses f to denote firm, j to denote industry, and t to denote year. The explanatory variable ESG_{jt} represents the ESG performance of firms, while the core explanatory variable GFP_{jt} measures the extent to which the treatment group is affected by GFP. The variable $Treat_{jt}$ is a dummy variable that distinguishes whether the industry is subject to GFP or not, and X_{jt} denotes other control variables. The model introduces individual firm fixed effects, industry effects, province effects, and time effects, with ε_{jft} denoting the disturbance term. The paper excludes non-restricted industries from being defined as a treatment group and portrays the magnitude of the treatment group affected by the policy. Firms in industries that are both restricted and have experienced a larger decline in pollution emissions are more affected by GFP. To ensure the validity of the double-difference model, it is necessary to confirm the parallel trends of the treatment and control groups before policy implementation and to ensure the certainty of the policy time. Before conducting the benchmark regression, we test the difference between the treatment and control groups before and after the policy implementation using the event study method. Additionally, we conduct a policy time uniqueness test to ensure no policy effect prior to 2016. Finally, we conduct the parallel trend test.

$$ESG_{jt} = \beta_0 + \sum_{k=-9, k \neq 0}^5 \beta_k GFP_{jt}^k + \theta X_{jt} + \lambda_f + \lambda_j + \lambda_p + \lambda_t + \varepsilon_{jft} \quad (2)$$

In the equation above, k represents the time difference between each year and 2016, while GFP_{kjt} represents the

implementation of GFP in a given year, as defined in the previous section. The model uses the year of GFP introduction in 2016 as the base period and examines the change in policy effects over time by testing parallel trends at the same time.

To obtain the ESG performance of enterprises, relevant information is collected from the CNRDS database. Compared to other domestic ESG evaluation systems, the CNRDS ESG database stands out for its scientific and comprehensive design. It refers to the internationally renowned MSCI ESG Stats Database and combines it with the actual situation of Chinese enterprises. The database comprehensively measures the ESG situation of listed enterprises in six aspects through 58 segmented indicators. Secondly, the database is intuitive and clearly expresses the dimensions of corporate ESG through corresponding dummy variables. This allows researchers to construct indices reflecting overall or specific aspects of corporate social responsibility, in line with their research direction. This paper refers to related literature (Lins et al. 2017) to construct indexes that reflect corporate ESG performance. To determine the strengths and concerns of each company, we first sum up the scores of the determination items in each subcategory. This gives us the performance score for each subcategory. We then subtract the strengths performance score from the concerns score of the corresponding subcategory to obtain the net strengths score of that subcategory. The enterprise's ESG net strengths score (ESG_net_str) is calculated by summing up the net strengths scores of each subcategory. This score reflects the overall ESG performance level of the enterprise.

3.2.1 Explanatory variables

The core explanatory variables take the form of $GFP_{jt} = Treat_{jt} \times \Delta ER_{j, 06-15}$. The former is the traditional double difference term, taking a value of 1 if the firm is in the restricted GF industry and the sample year is 2016 or later. The latter mainly characterises the degree of policy influence. The level of the industry's exposure to GF is measured by calculating a weighted average of the pollutant reductions achieved by each industry. This is expressed as:

$$\Delta ER_{j, 06-15} = -1 \times \sum_{p=1}^4 \Delta pollutin_{jp, 06-15} \quad (3)$$

This paper employs a standardised and equal-weighted linear summation method to determine the overall change in pollutant emissions for each industry. The selected pollutants are industrial solid waste, industrial waste gas, industrial fume emissions, and industrial wastewater discharges. The degree of influence by the policy is numerically opposite to the value of the change in pollutant emissions, which is adjusted with -1. The impact on the industry becomes more significant as the final $\Delta ER_{j, 06-15}$ value increases. Industry pollutant data is primarily sourced from the China

Environmental Statistics Yearbook and the China Statistical Yearbook from previous years. The two-digit industry codes from the National Economic Industry Classification and Codes (GB/T4754-2017) were used to match the restricted industries of GFP with the industries of the listed companies.

3.2.2 Control variables

To control for other characteristics that affect firms' ESG performance, this paper introduces a series of control variables. (See Supplementary Material A1 for descriptive statistics of variables).

4 Empirical analyses

4.1 Parallel trends and policy time uniqueness

Firstly, Eq. (2) is used to test the parallel trend assumption. The results indicate that the results of GFP in the years before the start of the policy are statistically insignificant, satisfying the common trend assumption. The analysis of the dynamic effects indicates that GFP have a significant driving effect on ESG in most years following their implementation, resulting in a long-term stabilising effect. Additionally, Eq. (1) was estimated using only the sample data prior to the policy's implementation, with the policy start date advanced by three and four years, respectively. As the policy start time is considered 'spurious' at this point, it is expected that the GFP has no significant effect on any of the firms' ESG performance behaviours. The results align with the expectation that GF has no significant effect on corporate ESG performance before the policy's start in 2016. It is reasonable to use 2016 as the policy time point. Please refer to Supplementary Material A2 for the results of the parallel trend test.

4.2 Benchmark regression

Table 1 presents the estimation results of Eq. (1). The first column shows the results without province and time fixed effects, while the second column shows the results with all control variables and fixed effects. The results suggest that GFP incentivise firms to enhance their ESG performance. After controlling for all fixed effects, the interaction term between GF-restricted industries and years after 2016 is not statistically significant. Using only the presence or absence of industry-level restrictions as a practical measure of GFP may be problematic. This is because there is some variation in environmental performance between restricted industries, which means that the intensity of their exposure to policy also varies. Simply using restricted industries as a

Table 1 GFP and corporate ESG performance

Variable	(1)	(2)
GFP	0.0428*** (0.0237)	0.0639*** (0.0254)
Treat	0.0428 (0.0427)	-0.0136 (0.0045)
Cons	-0.0746*** (0.4139)	0.4371*** (0.2864)
N	8256	8256
R ²	0.5726	0.7385

Robustness standard deviations are in parentheses, and ***, ** and * indicate significance at the 1 per cent, 5 per cent and 10 per cent significance levels, respectively

treatment group cannot correctly identify the effects of GFP. To identify the actual impacts brought by these policies, it is necessary to introduce the level of emission reduction of industries.

4.3 Robustness test

This section tests the robustness of the benchmark regression results in five aspects: the variability of the treatment and control groups, the randomness of the policy effects, the sample selection, the confounding of other policies and the macro factors. The results of the tests confirm the reliability of the benchmark regression results. Please refer to Supplementary Material A3 for the robustness test results.

4.4 Test of policy moderating effects

When GFP are effective, firms' responses are not unique. In addition to improving ESG performance in accordance with the policy requirements, the actual impact of the policy may be moderated through buffer or facilitation mechanisms. To test Hypothesis 2, this paper presents a model that examines the moderating effects of supply chain finance level (GYLJR), capital supply chain transparency (GYLTMD), and capital use efficiency (ZJSYXL) on GFP.

$$ESG_{ft} = \gamma_0 + \gamma_1 GFP_{jt} + \gamma_2 GYLJR_{ft} + \gamma_3 GFP_{jt} \times GYLJR_{ft} + \theta X_{ft} + \lambda_f + \lambda_j + \lambda_p + \lambda_t + \varepsilon_{jft} \tag{4}$$

$$ESG_{ft} = \pi_0 + \pi_1 GFP + \pi_2 GYLTMD_{ft} + \pi_3 GFP_{jt} \times GYLTMD_{ft} + \theta X_{ft} + \lambda_f + \lambda_j + \lambda_p + \lambda_t + \varepsilon_{jf} \tag{5}$$

$$ESG_{ft} = \pi_0 + \pi_1 GFP + \pi_2 ZJSYXL_{ft} + \pi_3 GFP_{jt} \times ZJSYXL_{ft} + \theta X_{ft} + \lambda_f + \lambda_j + \lambda_p + \lambda_t + \varepsilon_{jf} \tag{6}$$

Supply chain finance (GYLJR) is a method for financial institutions to offer financing and financial services to different participants by using the relationships and information

in a company's SC. It effectively addresses credit rationing constraints and enhances the level of corporate finance and overall performance through means such as information sharing, cooperative models, risk diversification, and traceability (Chod et al. 2020). GFP incentivise enterprises to improve ESG performance by providing financial capital subsidies and other means. SC finance enhances co-operation and trust between upstream and downstream firms in the SC to improve the chances of financial resources reaching firms (Cai et al. 2014). This financing method is based on direct relationships, which helps to avoid the challenges of traditional credit approval and risk assessment. We collect announcements of Chinese A-share listed companies from 2007–2021 using data mining techniques from the Oriental Wealth Network (OWN). We then screen out announcements related to 'SC finance' and classify them into 15 different business types. The number of SC finance business types implemented by each company is determined through clustering and filtering by the Word2Vec machine learning algorithm. This paper introduces the dummy variable GYLJR to indicate whether a company engages in SC finance business. A value of 1 indicates that the listed company carries out SC finance business in that year, while a value of 0 indicates that the listed company does not engage in SC finance business in that year. Additionally, this paper measures the level of engagement of various firms in the SC finance business by calculating the logarithm of the number of types of SC finance business in which a firm is involved out of the 15 types of supply chain finance business (+ 1 GYLJRType) and the logarithm of the frequency with which a firm mentions SC finance-related terms in all announcements made during the year (+ 1 GYLJRWord). Table 2, column (1), indicates that firms with a higher level of SC finance development are less

likely to improve their ESG performance. The development of SC finance reduces information asymmetry between enterprises and financial institutions, alleviates the agency problem between enterprises and financial institutions and logistics enterprises, reduces transaction costs between enterprises and financial institutions, and overcomes the FC of credit rationing. The regression results in Table 2 (2) to (3) indicate that the number of types of SC finance business carried out by listed companies (GYLJRType) and the number of times SC finance-related words are mentioned in all announcements made by enterprises in the same year (GYLJRWord) have a significantly negative effect on the improvement of ESG performance of enterprises by the GFP. The research suggests that the more types of SC finance a business engages in, the more frequently SC finance-related terminology appears in announcements. Furthermore, the more SC finance-related words mentioned in the announcements, the more significant the impact of SC finance in hindering the implementation of GFP aimed at improving the ESG performance of enterprises.

Supply chain transparency (GYLTMD) refers to the level of openness and transparency of information regarding the different links and participants involved in a SC. As per the information asymmetry theory, a transparent SC provides more accurate and comprehensive information, including a company's environmental policies, behaviours, and practices. Financial institutions can use this to assess firms' ESG risks and performance more accurately (Asante-Appiah and Lambert 2023). According to stakeholder theory, a transparent SC provides information and data needed by all parties, facilitating cooperation and joint efforts of stakeholders to achieve the SDGs (Barratt and Oke 2007). When considering corporate ESG, financial institutions and investors

Table 2 Moderating effects test

Variable	(1) GYLJR	(2) GYLJRType	(3) GYLJRWord	(4) GYLTMD_Num	(5) GYLTMD_Ratio	(6) ZJSYXL
GFP	0.0386*** (0.0217)	0.0234*** (0.0184)	0.0126** (0.0176)	0.0176*** (0.0218)	0.0153*** (0.0142)	0.0159*** (0.0234)
Interaction term	-0.0074** (0.0042)	-0.0056** (0.0037)	-0.0023* (0.0036)	0.0392*** (0.0239)	0.0243*** (0.0157)	0.0127 (0.0242)
Moderating the marginal effect						
25% quartile	0.0382*** (0.0206)	0.0239*** (0.0164)	0.0142** (0.0153)	0.0253*** (0.0195)	0.0258*** (0.0173)	0.0218*** (0.0263)
50% quartile	0.0359*** (0.0205)	0.0216*** (0.0146)	0.0135** (0.0142)	0.0474*** (0.0174)	0.0379*** (0.0168)	0.0269*** (0.0271)
75% quartile	0.0317*** (0.0176)	0.0207*** (0.0146)	0.0175** (0.0134)	0.0681*** (0.0169)	0.0471*** (0.0194)	0.0234*** (0.0285)
Cons	0.0216*** (0.3764)	0.0197*** (0.03642)	0.0195*** (0.03615)	0.7516*** (0.3182)	0.5272*** (0.0346)	-0.0725 (0.3761)
N	8256	8256	8256	8256	8256	8256
R ²	0.4825	0.4731	0.4628	0.7267	0.4271	0.6172

Robustness standard deviations are in parentheses, and ***, ** and * indicate significance at the 1 per cent, 5 per cent and 10 per cent significance levels, respectively

should also take into account stakeholders' interests. Transparent SC information can assist in evaluating the relationship between the firm and its stakeholders, as well as the social responsibility undertaken by the firm. In this paper, we construct a SC transparency indicator by measuring two dimensions: the number of large suppliers and customers that disclose their specific names (GYLTMD_Num) and the business share of large suppliers and customers that disclose their names (GYLTMD_Ratio). The GYLTMD_Num is a metric used to indicate the number of large suppliers and customers whose names are explicitly disclosed by listed companies. A higher value indicates a greater number of disclosed names. The GYLTMD_Ratio, on the other hand, is a metric used to indicate the ratio of the transaction value of large suppliers and customers whose names are explicitly disclosed by listed companies to the total transaction value of the top five suppliers and customers. A higher value indicates a higher level of transparency in the firm's SC. Table 2 shows that higher SC transparency leads to a more significant effect of GF on improving corporate ESG, as demonstrated by the results in columns (4) and (5).

The efficiency of capital use (ZJSYXL) is a measure of how effectively a company uses its capital. It is calculated using the total asset turnover ratio, which reflects the speed at which all assets flow from inputs to outputs during the operating period of the enterprise. A higher total asset turnover ratio indicates better overall asset operating capacity. ZJSYXL refers to the value and impact that a firm or organization generates when using its financing capital for investment and operational activities. However, the efficiency of fund usage does not significantly moderate the effect of the GFP on improving the ESG aspects of firms, as shown in column (6). This is because the implementation of GFP requires comprehensive consideration of various factors, such as technical requirements, market development, and legal regulations. The investment and operation process can be complex for enterprises, and differences between subjects can lead to uncertainty and variations in capital efficiency. Therefore, relying solely on capital efficiency to regulate the effect of GFP on improving corporate ESG may have limitations.

4.5 Mechanism test

The measure of cost of capital used in this study is the ratio of interest expenses to total bank loans. According to the cost of capital theory, firms use financing to support environmental, social responsibility, and SD projects. A high cost of finance increases the FC of firms, reduces available capital, and constrains environmental and social inputs. Lowering the cost of finance can help alleviate FC and increase firms' ability to finance ESG investments and improve performance. FC are associated with firms'

environmental and social investment behaviour (Eichholtz et al. 2010). Therefore, it is important to address these constraints to enable firms to undertake environmentally and socially responsible projects. GFP can help alleviate FC and provide more funds for firms to invest in ESG aspects by reducing the cost of financing. Therefore, these policies are expected to improve firms' ESG performance behaviour. According to the theory of FC, firms often face FC when investing in environmental protection and SD. GF assists companies in overcoming FC for environmental protection and SD projects. This mechanism provides additional access to finance, improving companies' ability to implement such projects.

Construct the following mediation effect model with M denoting the mediating variables financing cost (RZCB), financing channel (RZQD), supply chain efficiency (GYLXL) and managerial power (GLCQL).

$$M_{jt} = \alpha_0 + \alpha_1 GFP_{jt} + \theta X_{jt} + \lambda_f + \lambda_j + \lambda_p + \lambda_t + \varepsilon_{jft} \quad (7)$$

$$ESG_{jt} = \psi_0 + \psi_1 GFP_{jt} + \psi_3 M + \theta X_{jt} + \lambda_f + \lambda_j + \lambda_p + \lambda_t + \varepsilon_{jft} \quad (8)$$

To test the impact of GFP on the time of survival, survival analysis can be used since the consequence of the financing channel effect is mainly an increase in the time cost of money. In this study, 'survival' is defined as the state in which the new loan is equal to zero, 'death' as the state in which the new loan is greater than zero, and 'risk' as the probability of obtaining the new loan. The settings are as follows:

$$\ln h(t;x) = \beta_0 + \beta_1 Treat_f + \theta X_f + \varepsilon_f \quad (9)$$

The risk function is represented by $h(t; x)$. To calculate the new loans of firms, we use {(total borrowing at the end of the year—total borrowing at the beginning of the year)/total borrowing at the beginning of the year} and construct dummy variables for the duration of the new loan being zero and whether or not the new loan is eventually obtained. These variables are used as explanatory variables in this paper. To ensure result stability, we set the baseline risk using exponential, Weibull, and Gamma distributions. Additionally, we use the Cox model for parameter estimation.

Table 3, column (1) results show that GFP significantly increase firms' financing costs. When combined with column (2), the coefficient estimates of the core explanatory variables decrease, and there is a partially mediated effect of financing costs on ESG performance behaviour. This study measures financing access (RZQD) using the duration year in which firms did not receive new loans. Table 3, column (3), (4), (5), (6) present the results of the test for the financing channel effect. This can be interpreted as a

Table 3 Mechanism test results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	RZCB		RZQD- Expo- nents	RZQD-Weibull	RZQD-Gamma	RZQD-Cox	GYLXL		GLCQL	
GFP	0.0237*** (0.0012)	0.0528*** (0.0216)	-0.3517*** (0.0974)	-0.4628*** (0.0876)	-0.4827*** (0.8619)	-0.4876*** (0.0892)	0.0384*** (0.0915)	0.0481*** (0.0057)	-0.0416*** (0.1134)	0.0476*** (0.0213)
RZCB		0.3047*** (0.0946)								
GYLXL							0.007*** (0.0002)			
GLCQL										-0.4126*** (0.1014)
N	8256	8256	774	774	774	774	8256	8256	8256	8256
R ² /Chi2	0.7519	0.3862	113.7548	146.1956	137.4625	151.2783	0.6723	0.8273	0.6274	0.7842

Robustness standard deviations are in parentheses, and ***, **, and * indicate significance at the 1 per cent, 5 per cent and 10 per cent significance levels, respectively

semi-elasticity with respect to the risk function. In other words, it represents a change in the probability of occurrence of non-zero new loans as the impact of the GFP increases.

Supply chain efficiency (GYLXL) refers to the ability of firms to complete SC activities at the lowest cost, highest quality, and rapid response while satisfying customer demand (Cheng et al. 2024). GFP can improve SC efficiency by providing financing support and incentives for firms to invest in green technologies and cleaner production methods (Casey 2023). These policies motivate firms to adopt greener SC management practices that optimize resource use and reduce waste (Williams et al. 2013). Secondly, green SC management can reduce production costs and improve overall efficiency, in line with the cost leadership theory. Green financial policy encourages enterprises to invest in environmental technology innovation, which is in line with the technology innovation theory (Li et al. 2020). The study used the data envelopment analysis (DEA) model to calculate the company's SC efficiency (see Supplementary Material A4 for details of the calculation method). DEA presents several notable advantages over other methods. Firstly, DEA facilitates the simultaneous analysis of multiple input and output variables, enabling a holistic evaluation of SC efficiency, which is essential in SC management research. Secondly, DEA evaluates the relative efficiency of different decision-making units (e.g., firms or departments) by comparing them, thus identifying best practices and establishing benchmarks for improving the efficiency of other units. Furthermore, DEA does not impose specific distributional assumptions on the data, enhancing its flexibility and applicability in analyzing complex SC data. Lastly, DEA not only identifies highly efficient units but also highlights areas for improvement and potential in less efficient units, providing detailed recommendations for enhancement (Banker et al. 1984). This analytical approach offers a quantitative assessment of SC efficiency and clear pathways for improvement, aiding policymakers and corporate managers in better understanding and optimizing the implementation of GFP. As demonstrated in columns (7) and (8) of Table 3, the GFP has a significant impact on improving firms' SC efficiency and partially mediates the effect of enhancing ESG performance.

This paper introduces an innovative approach that uses the entropy power method to assess managerial power from four dimensions, totalling twelve indicators, based on Gao et al. (2024), Zhang et al. (2011) study. According to agency theory, there is an agency problem between company owners (shareholders) and company operators (management). Management may pursue its own interests at the expense of shareholders (Burke 2022). GFP direct capital flows to ESG-performing firms, enabling management to focus on ESG factors while pursuing firm profits to meet shareholders' and society's expectations for sustainable operations.

This theory is validated by columns (9) and (10) in Table 3. GFP incentivise corporate management to prioritise environmental sustainability by directing investors towards firms with good ESG performance (Bond and Zeng 2022). This financial orientation provides support to enterprises, but also requires explicit planning and execution of ESG performance to meet investor expectations (Barko et al. 2022). Secondly, GFP may result in firms facing environmental fines or additional costs, which could encourage management to adopt more environmentally friendly business practices and avoid incurring extra expenses. It is important for management to consider and implement sustainable and environmentally friendly business practices to avoid such costs (Moss et al. 2023).

4.6 Heterogeneity analysis

4.6.1 Level of urban innovation

Urban innovation significantly drives firm's improved ESG performance, while technological innovation has the most direct impact on ESG among all types of innovation activities (Moscona and Sastry 2023). However, traditional indicators of urban innovation capacity often rely solely on the number of patents, which presents a limitation in terms of measurement dimension. This paper uses the city-level innovation index from the Chinese Cities and Industries Innovativeness Report as a tertiary indicator for the innovation level dimension. This process results in the innovation index as a proxy variable for the level of green innovation in cities. The report estimates the average value of patents of different ages, taking into account the different ages of valid invention patents each year, and weights them according to the city dimension. Table 4 displays the estimation results for weak and strong innovation levels in columns (1) and (2), respectively. The study findings indicate that GF has an insignificant impact on ESG performance in regions with low levels of innovation. This suggests that areas with lower levels of urban innovation may lack a well-developed innovation ecosystem, including innovation platforms, research institutions, and human

resources. Enterprises are limited in their ability to develop and apply environmentally friendly and sustainable technologies. As a result, they cannot fully utilise the financial support of GFP to enhance ESG performance.

4.6.2 Level of supply chain digitization

SC digitisation involves using digital technologies in SC management to establish peer-to-peer and end-to-end data connectivity between SC members. This can improve the operational efficiency of SCs in areas such as demand forecasting, R&D and design, processing and manufacturing, wholesale and retail, and after-sales services (Li et al. 2020). In this study, we developed a scale for digitising the SC, based on previous research by Büyüközkan and Göçer (2018), Seyedghorban et al. (2020), Attaran (2020), and other scholars. Columns (3) and (4) of Table 4 present the results of the heterogeneity analysis of SC digitisation levels. The analysis indicates that firms with high SC digitisation levels are more likely to improve their ESG performance than other firms. This reflects the differences in firms' environmental awareness across SC digitisation levels. Firms with high levels of SC digitisation are able to collect, record and manage data and information in the SC more effectively (Brau et al. 2023). This enables organisations to more accurately understand the impact of their SC activities on ESG, improving information transparency and data reliability. This transparency and reliability assist organisations in identifying significant ESG risks and opportunities and taking appropriate measures to enhance ESG performance.

4.6.3 Strength of environmental regulation

While GFP provide incentives for firms to improve their ESG performance, existing studies have argued that environmental policies are difficult to implement effectively without strict enforcement (Wang et al. 2023). If penalties for polluting behaviours are not severe, external costs resulting from corporate pollution may still be indirectly borne by residents or financial institutions, reducing the incentives for firms to

Table 4 Heterogeneity analysis

Variable	(1) Low level of urban innovation	(2) High level of urban innovation	(3) Low SC digitisation	(4) High SC digitisation	(5) Low environmental regulatory intensity	(6) High environmental regulatory intensity
GFP	0.0327 (0.0242)	0.0873*** (0.0415)	0.0756 (0.0742)	0.0351***	0.0176 (0.0231)	0.1125*** (0.0458)
P-value for difference between groups	0.009	0.009	0.017	0.017	0.007	0.007
N	2658	2760	3061	5006	2658	2760
R ²	0.5187	0.0759	0.5273	0.7246	0.6134	0.7546

Robustness standard deviations are in parentheses, and ***, ** and * indicate significance at the 1 per cent, 5 per cent and 10 per cent significance levels, respectively

improve their ESG performance (Chen et al. 2023). This study measures the degree of environmental regulation (ER) by calculating the amount of money invested in pollution control of waste gas and water in the year in the location of the listed company as a proportion of the industrial output value in that year. This indicator reflects the intensity of the investment in ER of performance. Table 4 reports the estimation results under different levels of ER. Column (5) shows the estimation result for weak ER intensity, while column (6) shows the estimation result for strong ER intensity. The study finds that GFP provide significant incentives for firms to improve their ESG performance only in regions with higher ER intensity. Regions with higher ER often impose mandatory ESG requirements and penalise or withhold financing support for non-compliant firms. GFP in these cases act as a reward and punishment mechanism, encouraging firms to improve their ESG performance to meet the requirements and receive financing support. These incentives motivate companies to take green initiatives and improve their ESG performance.

5 Conclusions

5.1 Main findings

The study concludes that the implementation of green finance policies (GFP) has a positive effect on ESG performance, but the impact is not uniform and is moderated by the level of corporate SC finance and the transparency of SC. It is important to note that the study found that the impact of GFP on ESG performance varies depending on different corporate behaviours. Secondly, the analysis of the mechanism demonstrates that GFP impact ESG performance through three mechanisms: external FC on corporations, enhanced efficiency of internal SCs, and the suppression of managerial power. Finally, GFP have an asymmetrical impact on firms with different characteristics. Firms with higher levels of urban innovation are more active in improving their ESG performance. Similarly, firms with higher levels of SC digitisation are more likely to improve their ESG performance under GFP. Additionally, firms in regions with higher intensity of ER are significantly incentivised by GFP to improve their ESG performance.

5.2 Theoretical implications and practical contributions

This study contributes significantly to both the theoretical and practical domains of operations management by examining the impact of GFP on corporate ESG performance from a SC perspective. Theoretically, it establishes a comprehensive framework that integrates GFP with ESG performance,

enhancing the understanding of how financial policies can promote sustainable business practices. The detailed mechanism analysis, using a continuous double-difference model, elucidates how GFP affects corporate behavior by tightening external FC, improving internal SC efficiency, and reducing managerial power. Furthermore, it identifies the heterogeneous effects of GFP on firms with different characteristics, such as levels of urban innovation, SC digitization, and ER intensity, thereby enriching the theoretical foundations of GF.

Practically, the study shows that GFP can markedly enhance SC efficiency by encouraging investments in green technologies and cleaner production methods. It highlights the critical roles of SC transparency and capital use efficiency in optimizing ESG performance. The findings suggest that managers should adapt their strategies to their specific contexts, taking into account factors like urban innovation and SC digitization to maximize the benefits of GFP. Policymakers can use these insights to refine GFP frameworks, ensuring they provide sufficient support while promoting transparency and efficient capital use. Differentiated incentive mechanisms could reward firms that significantly improve ESG performance, creating a more supportive environment for SD.

5.3 Managerial implications

The findings of this study offer several significant managerial implications for the design and implementation of GFP and their influence on corporate ESG performance. Firstly, the study demonstrates that GFP can substantially enhance SC efficiency by providing financial support and incentives for firms to invest in green technologies and cleaner production methods, thereby improving overall ESG performance. Managers should thus integrate GFP into their financial planning to capitalize on these benefits and promote sustainable SC practices.

Additionally, the analysis underscores the critical role of SC transparency in moderating the effects of GFP on ESG performance. Firms with higher transparency levels are better equipped to meet the stringent requirements of GFP and secure financial support. Therefore, managers should prioritize enhancing transparency in their SCs through improved information disclosure and stakeholder communication.

Furthermore, efficient capital utilization is crucial for the effectiveness of GFP. Firms that manage their capital resources more efficiently are more likely to benefit from GFP, urging managers to focus on prudent financial management and investment in technologies that support sustainable practices. The study also reveals that the impact of GFP on ESG performance varies among firms with different characteristics, such as urban innovation levels, SC digitization, and ER intensity. Consequently, managers should tailor their

strategies to their specific contexts, considering these heterogeneous effects to maximize the benefits of GFP. Policymakers can leverage these insights to refine GFP frameworks, ensuring they provide adequate support to firms while promoting transparency and efficient capital use. Differentiated incentive mechanisms could be introduced to reward firms that significantly improve ESG performance, fostering a more conducive environment for SD.

5.4 Future work

This study provides profound insights into the impact of GFP on corporate ESG performance, elucidating the mechanisms through which these policies exert their influence. Nonetheless, several areas merit further investigation to deepen our understanding and enhance the practical implications of GFP. Firstly, future research should explore the long-term effects of GFP on ESG performance across diverse industries and regions. Although this study offers a comprehensive analysis using data from Chinese A-share listed companies, broadening the scope to encompass a wider array of sectors and geographic areas could yield more generalizable findings. Moreover, the interplay between GFP and other regulatory or market-based instruments remains an under-explored area. Understanding how GFP interacts with carbon pricing mechanisms, renewable energy incentives, and other sustainability-focused regulations could reveal synergistic effects and potential conflicts, enabling policymakers to design more integrated and coherent frameworks for promoting SD. Finally, the behavioral responses of firms to GFP, particularly regarding managerial decision-making and strategic planning, warrant closer scrutiny. Understanding how managers perceive and react to GFP could uncover the underlying motivations and barriers to adopting sustainable practices, which would be instrumental in designing more effective communication and engagement strategies to foster a culture of sustainability within organizations.

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Data availability Data will be made available on request.

Declarations

Ethics approval and consent to participate Not applicable.

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