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ESG AND GREEN TRANSITION OF ENTERPRISES: A PERSPECTIVE FROM EMISSION REDUCTION AND DEVELOPMENT

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Abstract. Using data from 2009 to 2020 of A-share listed firms in China, this study investigates how ESG (Environmental, social, and governance) impacts corporate green transition (GT) from two perspectives: carbon emission intensity and total factor productivity. Results show that ESG significantly enhances corporate GT. Channel analysis shows that ESG improves the financing environment, optimizes environmental governance strategies, and improves the information environment, thereby promoting corporate GT. After the implementation of the *new Environmental Protection Law* (*EPL*) and the *Environmental Protection Tax Law* (*EPTL*), the GT with ESG advantages is significantly enhanced compared to those without ESG advantages. Heterogeneity analysis shows that the positive effects of ESG are more pronounced in firms with low availability of green credit and high levels of greenwashing. In addition, social responsibility of ESG has the greatest effect in enhancing GT, and ESG uncertainty can weaken the promotion effect of ESG on GT. The industry spillover effect test found that ESG has an industry emission reduction governance effect, and there is a peer effect of mutual influence on carbon emissions decisions among enterprises. Overall, our results reveal that ESG can promote GT to achieve sustainable development.

Keywords: ESG, green transition, emission reduction, development, spillover effects, peer effects.

JEL Classification: Q56, G24.

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1. Introduction

The escalating severity of environmental issues, natural disasters, and climate risks has made green sustainable development a global imperative (Chen et al., 2021; Wang et al., 2019; Yu et al., 2021). As key drivers of socioeconomic wealth and major consumers of natural resources, enterprises play a critical role in achieving a low-carbon transition, and accelerating their Green Transformation (GT) is essential (Lin et al., 2021a). However, corporate GT faces significant challenges, including substantial capital requirements, high risks, long payback periods, and negative externalities, which often reduce companies' motivation to transform. Addressing the resulting financing constraints and information asymmetry is therefore crucial. ESG practices help firms balance economic efficiency with sustainable development and assist investors in evaluating long-term sustainability for informed decision-making (Apergis et al., 2022). Despite its importance, how firms reconcile emission reduction with development within ESG frameworks remains underexplored. This study examines how ESG improvements

affect corporate GT, aiming to enhance investor awareness, boost corporate competitiveness, and advance sustainable development. In the context of green development, it also provides new research directions and applications for classical economic theory by assessing the robustness and long-term value of ESG investments.

ESG influences GT through three primary mechanisms. First, it improves financing conditions by helping firms secure preferential green credit and guiding capital toward low-carbon projects, thereby easing financial constraints (Tan & Zhu, 2022). Second, it optimizes environmental governance by strengthening corporate environmental ethos, boosting green investment, and enhancing green innovation capabilities (He et al., 2023). Third, it increases information transparency, reducing asymmetry with stakeholders and enabling better assessment of green projects by financial institutions, which reinforces the internal drive for GT (Reber et al., 2022).

Previous research has mainly studied what affects corporate GT, focusing on environmental regulations and company-level factors. Specifically, studies have analyzed how different environmental rules influence GT (Chen et al., 2023a; Du et al., 2021; Lu et al., 2022; Weber & Neuhoff, 2010; Zeng et al., 2023). Additionally, research shows that a business's own resources and capabilities influence its GT (Yang et al., 2020), and that stakeholders' environmental awareness also plays a role (Li & Lv, 2021). While existing studies have thoroughly explored factors affecting GT, less is known about how businesses can overcome financing challenges and information gaps to advance it. We measure corporate GT by looking at both emission reduction and economic development. Specifically, we use Carbon Emission Intensity (CEI) for emissions and Total Factor Productivity (TFP) for development. We find that ESG promotes GT by improving the financing environment, optimizing environmental governance strategies, and improving the information environment. Heterogeneity analysis shows that in samples with high levels of green credit and low levels of greenwashing, the promotion effect of ESG on the GT of enterprises will be significantly weakened. Our deeper analysis reveals that the social responsibility aspect of ESG has the strongest effect on improving GT. However, uncertainty in ESG can reduce how well ESG helps listed companies advance GT.

This study makes several important contributions to existing literature. First, this study explores how informal environmental rules affect corporate GT, adding to existing research on what drives this transition. While past studies mostly focus on the effects of formal environmental rules and company-specific factors (Fan et al., 2022; Oyewo, 2023; Pástor et al., 2021; Wang et al., 2022, 2023; Wu et al., 2023; Yu & Zhang, 2021; Zhao et al., 2020), we investigate how ESG can address financing constraints and information asymmetry to promote corporate GT from the perspective of informal environmental regulation, thus filling a research gap. Second, this study enriches the mechanism of ESG promoting GT of enterprises from multiple perspectives of financing environments, environmental governance strategy and external information environment. At the same time, it explores the heterogeneity characteristics of ESG's GT effect from the perspective of green credit level and greenwashing degree. This study offers both theoretical and practical value. It supports stronger policies for developing ESG and advancing corporate GT. It also gives researchers and business professionals real-world evidence to better understand ESG's importance. Third, this study expands research on ESG's environmental impact. Current studies mainly focus on how ESG affects corporate

financial and operational areas, like performance, innovation, and risk (Avramov et al., 2022; Chen et al., 2023b; Lins et al., 2017; Pástor et al., 2021; Saygili et al., 2022), while paying relatively little attention to ESG environmental impact. This study advances ESG research by examining its environmental impact and its role in low-carbon transformation and development.

2. Theoretical analyses and research hypotheses

Based on the synthesized insights from prior research, ESG drives corporate GT through multiple interconnected mechanisms. Firstly, it provides a foundational framework for managing sustainability risks and opportunities, which enhances long-term value by cutting costs, boosting efficiency, and fostering innovation – enabling firms to capitalize on new market trends (Atkins et al., 2023; Li et al., 2023; Raimo et al., 2021). Secondly, ESG improves the financing environment for green initiatives, helping firms secure diverse funding sources such as green bonds and impact investments (Tan & Zhu, 2022). Thirdly, it strengthens environmental governance by promoting sound policies, stakeholder engagement, and operational transparency, thereby reducing ecological harm and enhancing accountability (He et al., 2023). Finally, ESG elevates the information environment through accurate disclosure and active dialogue, building stakeholder trust and aligning corporate actions with broader sustainable development goals (Reber et al., 2022). Accordingly, we propose:

H1: *ESG promotes corporate GT.*

Under strengthened environmental regulations, firms with established ESG strengths demonstrate a notably higher degree of GT compared to those without, a phenomenon underpinned by "regulatory arbitrage." Such firms are better positioned to adapt to and comply with new regulatory demands, having already embedded practices such as greenhouse gas reduction, energy efficiency improvements, and waste minimization (He et al., 2023). This readiness not only mitigates non-compliance risks and potential penalties, but also confers a competitive edge (Zheng et al., 2023). Furthermore, robust ESG performance helps firms capture growing consumer preference for sustainable products, thereby enhancing market appeal and sales (Aksoy et al., 2022). Accordingly, we propose:

H2: *Enterprises with ESG advantages show a significantly higher degree of GT compared to those without such advantages, particularly in the face of increased environmental regulatory pressures.*

Green credit availability influences corporate GT. Drawing on signaling theory, firms employ actions to convey their capabilities and values to stakeholders (Taj, 2016). Companies without green credit may leverage ESG to signal their sustainability commitment and differentiate themselves from financially-oriented peers (Bătae et al., 2021). Through ESG initiatives, they demonstrate competence in managing environmental and social risks while underscoring a long-term growth orientation – enhancing investor confidence, reputation, and access to sustainability-sensitive markets (Murè et al., 2021). In contrast, firms that receive green credit may treat ESG instrumentally, primarily for compliance or financial gain, leading to superficial implementation with limited impact on GT (Roy, 2023). Therefore, we argue

that ESG contributes more significantly to GT in firms without green credit than in those with it. Accordingly, we propose:

H3a: *With other conditions being limited, the lower the availability of green credit for enterprises, the more significant the role of ESG in promoting corporate GT.*

Greenwashing, where firms exaggerate or misrepresent environmental actions to enhance their image and competitiveness (Szabo & Webster, 2021), may nonetheless drive increased investment in ESG initiatives. Such firms, aware of stakeholder expectations, may intensify ESG spending and reporting to offset negative perceptions and bolster their reputation (Yu et al., 2020). In contrast, firms with less greenwashing face lower stakeholder pressure and may invest less actively in ESG, thereby limiting its contribution to GT (Lee & Raschke, 2023; Pizzetti et al., 2021). This dynamic underscores the importance of transparency and accountability in sustainability practices: firms that authentically implement and communicate ESG efforts are more likely to foster meaningful environmental progress (Baldi & Pandimiglio, 2022). Accordingly, we propose:

H3b: *With other conditions being limited, a higher level of corporate greenwashing leads to a stronger positive effect of ESG on corporate GT.*

3. Data, variable and model

3.1. Data

Due to the limitations of ESG and enterprise carbon emission data, we take a sample of A-share listed companies from 2009 to 2020. Our data sources are as follows: First, we manually collect the data on carbon emissions, fossil fuel consumption and electricity / heat usage from the annual social responsibility reports, sustainability reports and environmental reports of the enterprises. Subsequently, we supplement and organize this information using the CSMAR database. Finally, we calculate the carbon emissions based on the methods issued by the *National Development and Reform Commission*[1]. Secondly, the ESG rating information is from *Huazheng* dataset[2]. Thirdly, the financial information of enterprises comes from CSMAR database[3] and Wind database. To ensure the accuracy of the data, we exclude the more special financial industry and other industries with fewer observations, and exclude samples with missing or obviously inconsistent with accounting standards for key variables.

[1] The National Development and Reform Commission (NDRC) of China establishes the country's carbon emission calculation methodologies. These standardized approaches are broadly implemented to ensure consistency with national environmental and emission reduction goals.

[2] The Huazheng ESG Rating System adapts international ESG practices to China's context, providing environmental, social, and governance ratings for Chinese A-share and Hong Kong stock issuers (https://www.chindices.com/).

[3] The firm-level data is accessed from China Stock Market and Accounting Research Database (CSMAR), which covers China's publicly listed firms on the Shanghai or Shenzhen stock exchanges (https://data.csmar.com/).

3.2. Variables

3.2.1. Corporate GT measures

GT in manufacturing focuses on enhancing resource efficiency and labor productivity while reducing energy consumption, pollution, and environmental impact. It also strengthens sustainable development capabilities. For firms, GT aims to transform operations to achieve both environmental and economic gains. Thus, the core extension of GT encompasses emission reduction and developmental efficiency. Regarding emission reduction, addressing climate issues is urgent, and "carbon reduction" has become a global priority. In terms of development, improvements in production efficiency and resource allocation are central. Accordingly, GT can be measured through two lenses: CEI and efficiency optimization.

CEI measures the amount of carbon dioxide released per unit of economic output. It is widely used to assess carbon emission levels and the environmental impact of human activities. A lower CEI indicates lower carbon emissions for a given production process or activity, reflecting a more sustainable and environmentally friendly approach. We calculate corporate CEI as the ratio of greenhouse gas emissions (including CO_2 and CO) disclosed by companies to their business revenue. Subsequently, we recalculated corporate carbon emissions using industry-level data from the CEADs database. This involved determining the ratio of industry emissions to industry operating costs and applying it as a weighting factor. Additionally, we constructed an adjusted CEI (*CEI_adj*) as a robustness measure. In estimating firm-level TFP, the OP and LP methods are widely employed for their ability to address endogeneity concerns and sample selection bias (Olley & Pakes, 1992; Levinsohn & Petrin, 2003). Given its ability to mitigate sample attrition, the LP method represents an improvement over the OP approach. Consequently, we employ the LP method to estimate TFP (*TFP_lp*), while utilizing the OP method (*TFP_op*) for robustness checks.

3.2.2. Measure of corporate ESG

Given the growing significance of ESG information, third-party rating agencies have introduced specialized ESG evaluation products. Among these, the Huazheng Index has assessed the ESG performance of A-share and bond issuers since 2009, achieving comprehensive coverage of all A-share listed companies. This index is widely adopted in both academic and industry practice. Considering its historical applicability and breadth of coverage, we employ the Huazheng ESG rating as the proxy variable for corporate ESG performance. The rating system comprises nine tiers: C, CC, CCC, B, BB, BBB, A, AA, and AAA. Following Lin et al. (2021b), we assign numerical values from 1 to 9 to these ratings in ascending order, with higher values denoting stronger ESG performance.

3.2.3. Control variables

Consistent with the Prior studies (Lee et al., 2023; Li et al., 2019; Lu et al., 2022), we include the main characteristics: Financial Leverage (*LEV*), State Ownership (*SOE*), Asset Structure (*TANG*), Intangible Assets Ratio (*INTANG*), Firm Size (*SIZE*), Firm Age (ln*AGE*), R&D intensity (*RD*), director with overseas background (*BOARD*), number of employees (ln*Employees*). Table 1 presents the description and definition of the control variables.

Table 1. Definition of the control variables

Variables	Definition
LEV	Total liabilities over total assets
SOE	A dummy variable that equals 1 if the firm is controlled by the state, and 0 otherwise
TANG	The ratio of the sum of net fixed assets and net inventory to total assets
INTANG	Net intangible assets over total assets
SIZE	The natural logarithm of the total assets
ln*AGE*	The natural logarithm of one plus the difference between the year of establishment and the statistical year
RD	R&D investment over operating revenues
BOARD	Number of directors with overseas background
ln*Employees*	Natural logarithm of the number of employees

3.3. Models

We examine how ESG affects corporate GT. Specifically, we test whether firms with strong ESG practices show greater GT improvements than those without ESG advantages – especially when environmental regulations change. We establish Models (1) and (2) to test Hypotheses 1–2 respectively:

$$GT_{it} = \alpha + \alpha_1 ESG_{it} + \gamma X_{it} + v_t + \eta_j + \varphi_p + \varepsilon_{it}, \quad (1)$$

where GT_{it} is the degree of GT of firm i in year t. ESG_{it} is the ESG rating of enterprise i in year t. To reduce omitted variable bias, we add firm-level control variables and fixed effects to our model. Specifically, φ, η, and v represent province, industry, and year fixed effects[4].

To investigate whether the promotion effect of ESG advantages on GT will increase or decrease under the influence of environmental regulation due to exogenous policy shocks, compared to enterprises without ESG advantages, we draw on Gilje and Taillard (2016) and use the DID estimation method to construct Model (2) below to test Hypothesis 2.

$$GT_{it} = \beta_0 + \beta_1 Treat \times Time + \beta_2 Treat + \beta_3 Time + \gamma X_{it} + v_t + \eta_j + \varphi_p + \varepsilon_{it}, \quad (2)$$

where *Time1* marks years since the 2015 *new Environmental Protection Law* (*EPL*) started (1 = 2015 onward; 0 = before 2015). *Time2* does the same for the 2018 *Environmental Protection Tax Law* (*EPTL*) (1 = 2018 onward; 0 = before 2018). *Treat* identifies companies with ESG advantages: high-rated firms (treatment group = 1) versus low-rated firms (control group = 0), using yearly median ESG ratings. Our focus is the *Treat*×*Time* coefficient, showing how environmental policies affect corporate GT differently for ESG-advantaged firms versus others.

[4] What needs to be noted is that the variation of key variables was mainly found among different firms within the same industry, which means there are significant differences in ESG and CEP between different firms within the same industry. However, the variation within a firm group was relatively small within the sample interval. Therefore, the industry fixed effect was chosen as the control variable instead of the individual firm fixed effect.

4. Results and discussion

4.1. Summary statistics

Table 2 presents summary statistics. The average *CEI* is approximately 1.3805 tonnes/million (SD = 0.7994), with a range of 3.4438. This indicates generally high CEI levels but significant variation across firms. TFP averages are 8.2464 (LP method, SD = 1.0248) and 6.6268 (OP method, SD = 0.8519), showing higher productivity under LP but similar value distributions. The mean ESG rating of 4.0687 suggests overall low ESG performance. Among the control variables, firm size averages 22.2387, indicating considerable sample diversity. The mean financial leverage is 43.45%, suggesting generally reasonable debt levels. R&D intensity ranges widely from 0 to 22.3%, consistent with China's innovation-driven strategy, where firms in competitive sectors invest heavily in R&D, while others engage minimally. The proportion of SOEs is nearly even (mean SOE = 0.4112), aligning with China's mixed-ownership structure: SOEs dominate strategic sectors, while private firms lead in consumer markets. Board internationalization varies considerably (0–11 directors), highlighting differences in global exposure: multinational and tech firms prioritize international expertise, whereas traditional firms exhibit limited overseas engagement.

Table 2. Descriptive statistics

Variable	N	Mean	Std.	Min.	Max.
CEI	21,075	1.3805	0.7994	0.5673	4.0111
CEI_adj	21,075	0.8980	0.4638	0.0197	2.5424
TFP_lp	21,075	8.2464	1.0248	3.7827	11.8995
TFP_op	21,075	6.6268	0.8519	2.3773	9.9937
ESG	21,075	4.0687	1.0921	1	8
LEV	21,075	0.4345	0.2052	0.0530	0.8943
TANG	21,075	0.3922	0.1678	0.0468	0.7932
INTANG	21,075	0.0480	0.0489	0	0.3143
SIZE	21,075	22.2387	1.3234	19.8377	26.3685
ln*AGE*	21,075	2.1701	0.7539	0	3.3322
RD	21,075	3.2338	3.5791	0	22.3
SOE	21,075	0.4112	0.4921	0	1
BOARD	21,075	0.7369	1.1119	0	11
ln*Employees*	21,075	7.7909	1.2793	2.1972	13.2228

4.2. Analyzing the impact of ESG on corporate GT

4.2.1. Baseline results

Table 3 provides the results of ESG on corporate GT. The dependent variables in Columns (1)–(2) are *CEI*, while those in Columns (3)–(4) are *TFP_lp*. The coefficients of *ESG* in in Columns (1)–(2) are statistically negative, supporting the idea that ESG performance can reduce corporate CEI. The coefficients of *ESG* in in Columns (3)–(4) are significantly positive, supporting the idea that ESG performance can improve TFP. Taking the results in Columns (2) and (4),

the estimated coefficients of *ESG* are –0.0260, and 0.0257, respectively, suggesting that the corporate CEI reduces by 1.88% (–0.0260 divided by all firm *CEI* mean 1.3805), and the TFP increases by 0.31% (0.0257 divided by all firm *TFP_lp* mean 8.2464).

Table 3. Baseline results

	CEI		*TFP_lp*	
	(1)	(2)	(3)	(4)
ESG	–0.0149***	–0.0260***	0.1912***	0.0257***
	(0.0053)	(0.0055)	(0.0060)	(0.0034)
LEV		0.0370		0.3129***
		(0.0347)		(0.0274)
TANG		–0.1635***		–0.8970***
		(0.0387)		(0.0320)
INTANG		0.5291***		–1.2217***
		(0.1392)		(0.0955)
SIZE		0.0751***		0.4682***
		(0.0088)		(0.0067)
ln*AGE*		0.1091***		–0.0037
		(0.0097)		(0.0060)
RD		–0.0144***		–0.0392***
		(0.0021)		(0.0015)
SOE		–0.0095		0.0832***
		(0.0158)		(0.0098)
BOARD		0.0102*		0.0190***
		(0.0058)		(0.0030)
ln*Employees*		–0.0056		0.1624***
		(0.0076)		(0.0065)
Constant	1.4410***	–0.3123**	7.4686***	–3.1741***
	(0.0223)	(0.1518)	(0.0251)	(0.1119)
Province/Industry/Year FE	Yes	Yes	Yes	Yes
Observations	21,075	21,075	21,075	21,075
Adj_R^2	0.0368	0.0682	0.2604	0.7693

Note: Standard errors are clustered at the firm level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively (same table below).

4.2.2. Endogeneity

Existing evidence suggests that ESG promotes corporate GT, though reverse causality remains a concern. For one thing, stronger ESG performance fosters GT through market incentives and external oversight. For another thing, as firms intensify energy-saving and emission-reduction efforts – core social responsibility objectives – they often align corporate strategy and human capital with green targets, which in turn elevates their ESG ratings and advances sustainability goals. Prior studies frequently employ industry- or regional-level ESG averages as Instrumental Variables (IVs) for ESG (Breuer et al., 2018). While these generally satisfy

correlation conditions, they may violate the exclusion restriction by directly influencing GT independent of firm ESG (Gormley & Matsa, 2014). To address this, we adopt two alternative IVs from prevailing research practice: the number of ESG investment funds held by a firm (*FQ*) and the natural logarithm of their market value (ln*FV*).

Public funds, as influential institutional investors, significantly shape corporate ESG practices through their investment decisions. By "voting with their feet," they incentivize and monitor firms, thereby improving corporate governance (Dimson et al., 2015). ESG-themed funds specifically enhance corporate ESG performance by selectively investing in high-ESG firms and promoting sustainability across industries. Dyck et al. (2019) further show that institutional investors often use private engagements – such as direct communication with management – to constructively influence ESG practices, a method widely regarded as effective by fund managers. The creation and scale of ESG funds reflect institutional emphasis on governance and sustainability, linking them clearly to corporate ESG performance. As these fund-level decisions are made independently by fund managers based on market conditions and strategic objectives – not firm-specific characteristics – they satisfy the exogeneity requirement for instrumental variables. Thus, both the quantity of ESG investment funds (*FQ*) and their market value (ln*FV*) serve as valid instruments for corporate ESG.

The first stage results in Columns (1) and (3) of Table 4 show that both IVs are positive, which means that the more ESG investment funds a company is held by or the larger the market value of its shares, the better its ESG performance. The results of the F test, identification deficiency test, and weak instrument variable test all confirm the rationality of the selection of IVs. The second stage results in Columns (2) and (4) show that the coefficients of *ESG_IV* are negative and positive, and the magnitude of the coefficient is about 5.78 (–0.1502 divided by –0.0260) and 14.67 (0.3770 divided by 0.0257) times that of the baseline coefficient, respectively. Therefore, after controlling for endogeneity using IVs, the results remain valid.

Table 4. IV estimation results

	CEI		TFP_lp	
	(1)	(2)	(3)	(4)
	Phase I: *ESG*	Phase II: *CEI*	Phase I: *ESG*	Phase II: *TFP_lp*
ESG_IV		–0.1502**		0.3770***
		(0.0649)		(0.0449)
FQ	0.0298**		0.0298**	
	(0.0130)		(0.0130)	
ln*FV*	0.0103***		0.0103***	
	(0.0010)		(0.0010)	
F value	92.00[0.000]		92.00[0.000]	
Kleibergen-Paap rk LM	180.89[0.000]		180.92[0.000]	
Cragg-Donald Wald F	91.20		91.20	
Hansen J	2.254[0.1333]		3.111[0.0778]	
Controls	Yes	Yes	Yes	Yes
Province/Industry/Year FE	Yes	Yes	Yes	Yes
Observations	19691	19691	19691	19691

4.2.3. Robustness tests

4.2.3.1. Propensity Score Matching (PSM)

We use PSM to reduce sample differences. High ESG-rated firms form the treatment group, while low-rated firms serve as the control group. We use financial leverage (*LEV*), state ownership (*SOE*), asset structure (*TANG*), intangible assets ratio (*INTANG*), firm size (*SIZE*), firm age (ln*AGE*), R&D intensity (*RD*), director with overseas background (*BOARD*), number of employees (ln*Employees*) as covariates. In the results of estimation after matching with PSM method (Columns (1)–(2) in Table 5), the coefficients of *ESG* are significantly, indicating that the impact of ESG performance on enterprise CEI remains negative, while its impact on TFP is positive.

4.2.3.2. Heckman two-stage model

Considering that when issuing ESG ratings, rating agencies may choose large enterprises with relatively abundant information for disclosure, there may be sample selection issues in the model. To address the issue of model self-selection, we adopt the Heckman two-stage model to handle endogeneity (Heckman, 1979). In the first stage, the IVs for the selection equation are the number and market value of ESG fund holdings in the enterprise. Results show significant *IMR* coefficients, confirming our model properly controls for self-selection bias. Meanwhile, consistently significant *ESG* coefficients indicate robust findings even after accounting for this bias.

Table 5. PSM and Heckman two-stage model estimation

	CEI	*TFP_lp*	*CEI*	*TFP_lp*
	(1)	(2)	(3)	(4)
ESG	–0.0257***	0.0155***	–0.0222***	0.0218***
	(0.0099)	(0.0059)	(0.0057)	(0.0032)
*IMR**			–0.0320	0.1852***
			(0.1065)	(0.0344)
Constant	0.2760	–3.0905***	–0.2565	–3.1233***
	(0.3264)	(0.2403)	(0.2139)	(0.0985)
Controls	Yes	Yes	Yes	Yes
Province/Industry/Year FE	Yes	Yes	Yes	Yes
Observations	4,469	4,469	21,479	24,995
Adj_R^2	0.0640	0.7679	0.0564	0.7756

4.2.3.3. Alternative ESG and corporate GT measurement

We also replace the core variables in this study. For one thing, we replace the explained variable. As mentioned earlier, we estimate by replacing the explained variable with *CEI_adj* and *TFP_op* respectively, as shown in Columns (1)–(2) of Table 6. The Equation for the *CEI_adj* is:

$$CEI\_adj = \frac{\left(\frac{\text{Industry carbon emissions}}{\text{Industry prime operating cost}} + 1\right) \times \text{Corporate operating cost}}{\text{Corporate operating revenue}}. \quad (3)$$

For another thing, we replace the explanatory variable. First, we change the assignment method of ESG ratings, assigning grades C-CCC, B-BBB, and A-AAA to values 1, 2, and 3 respectively (*ESG_adj*). Second, we use Wind ESG rating indicators and Wind ESG comprehensive score indicator data for estimation (*Wind_ESG1*; *Wind_ESG2*). The results are shown in Columns (3)– (8) of Table 6. The results show that when *CEI* is the dependent variable, the coefficient of *ESG* (*ESG_adj*; *Wind_ESG**) is negative. In contrast, when *TFP_lp* is the dependent variable, the coefficient of *ESG* (*ESG_adj*; *Wind_ESG**) is positive. The results obtained from different assignment and measurement methods are consistent with the basic conclusion.

Table 6. Alternative ESG and corporate GT measurement

	CEI_adj	*TFP_op*	*CEI*	*TFP_lp*	*CEI*	*TFP_lp*	*CEI*	*TFP_lp*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG	–0.0062**	0.0254***						
	(0.0028)	(0.0033)						
ESG_adj			–0.0410***	0.0486***				
			(0.0131)	(0.0083)				
Wind_ESG1					–0.0432***	0.0161**		
					(0.0135)	(0.0071)		
Wind_ESG2							–0.0500***	0.0223***
							(0.0151)	(0.0077)
Constant	0.4491***	–4.3234***	–0.2522**	–3.2116***	–0.0767	–4.1791***	–0.0581	–4.1994***
	(0.0783)	(0.1079)	(0.1258)	(0.1120)	(0.2965)	(0.1758)	(0.2977)	(0.1758)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province/ Industry/Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,075	21,075	21,075	21,075	7,358	7,358	7,359	7,359
Adj_R^2	0.2511	0.6932	0.0676	0.7691	0.0615	0.7208	0.0617	0.7210

4.2.3.4. Multidimensional fixed effects and changing cluster-robust standard errors

First, we use multidimensional fixed effects. To control for unobserved industry and province factors, our baseline regression includes industry, city, and year effects. However, omitted variables could still cause endogeneity. We therefore add industry-year and province-year interaction terms to account for macro-level influences. Second, we adjust cluster-robust standard errors. Since provincial factors may correlate, we cluster standard errors at this level. Table 7 confirms ESG coefficients remain statistically significant and robust.

4.2.3.5. Exclude interference from important environmental policies

First, China's 2013 "Ten Measures for Atmosphere" (*Action Plan for Air Pollution Prevention*) is considered its toughest environmental policy. This regulation may impact corporate GT. To eliminate the interference of this environmental policy on the baseline conclusion, we regressed after removing the enterprise samples from the 57 high-target cities under the "Ten Measures for Atmosphere". The results are shown in Columns (1)–(2) of Table 8. Second, in

2013 and 2014, China officially launched pilot carbon emissions trading programs in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen. To prevent carbon trading pilots from affecting our results, we reran regressions after removing firms in pilot areas. The results are shown in Columns (3)–(4). Third, in 2014, China's Ministry of Environmental Protection introduced the Interim Measures for Interviews. This policy required local government leaders who did not meet their environmental responsibilities to be formally interviewed. It also used direct orders to push businesses to lower their pollution emissions. During our study period, 73 cities were interviewed under this system. To avoid bias in our findings caused by these interviews, we excluded companies located in these interviewed cities from our analysis and then reran the analysis. The results are shown in Columns (5)–(6). Fourth, on January 1, 2018, China enacted the *EPTL*. This shift from environmental fees to taxes could influence how companies manage their pollution discharge, potentially affecting

Table 7. Multidimensional fixed effects and changing cluster-robust standard errors

	CEI	*TFP_lp*	*CEI*	*TFP_lp*
	(1)	(2)	(3)	(4)
ESG	–0.0256***	0.0284***	–0.0260***	0.0257***
	(0.0057)	(0.0035)	(0.0086)	(0.0071)
Constant	–0.3102**	–3.2198***	–0.3123*	–3.1741***
	(0.1565)	(0.1113)	(0.1841)	(0.2294)
Controls	Yes	Yes	Yes	Yes
Province FE	No	No	Yes	Yes
Industry FE	No	No	Yes	Yes
Year FE	No	No	Yes	Yes
Industry×Year FE	Yes	Yes	No	No
Province×Year FE	Yes	Yes	No	No
Observations	21,075	21,075	21,075	21,075
Adj_R^2	0.0594	0.7717	0.0682	0.7693

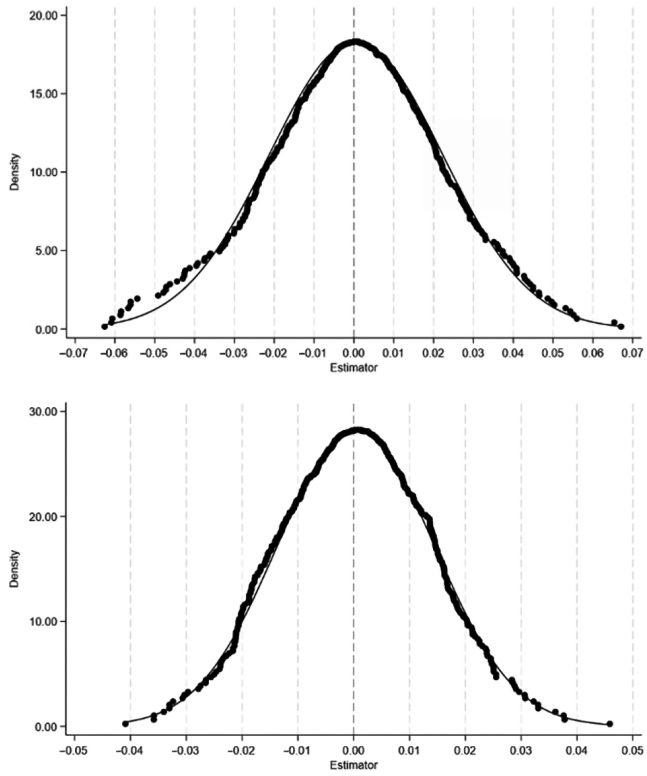
Table 8. Exclude interference from important environmental policies

	CEI	*TFP_lp*	*CEI*	*TFP_lp*	*CEI*	*TFP_lp*	*CEI*	*TFP_lp*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG	–0.0224***	0.0240***	–0.0320***	0.0246***	–0.0250***	0.0246***	–0.0285***	0.0182***
	(0.0082)	(0.0052)	(0.0067)	(0.0042)	(0.0060)	(0.0037)	(0.0072)	(0.0045)
Constant	–0.0604	–3.3494***	–0.3489*	–3.3967***	–0.3198**	–3.1452***	–0.3510**	–3.2036***
	(0.2280)	(0.1699)	(0.1982)	(0.1464)	(0.1625)	(0.1204)	(0.1688)	(0.1507)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province/ Industry/ Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,496	9,496	13,551	13,551	18,006	18,006	12,310	12,310
Adj_R^2	0.0573	0.7587	0.0716	0.7589	0.0719	0.7743	0.0723	0.7588

our baseline findings. To isolate the impact of this "fee-to-tax" change on our results, we excluded 12 provinces with higher environmental tax rates[5], and then reran the regression analysis. The results are shown in Columns (7)–(8). The results show that the coefficients of *ESG* remain significant, indicating robust conclusions.

4.2.3.6. Placebo test

To verify that ESG's impact on corporate GT is not random, we conducted a placebo test. We randomly reassigned ESG scores to each company-year observation 500 times, creating simulated explanatory variables based on actual data distributions. Figure 1 displays the resulting coefficients and p-values. The results indicate that the average pseudo-coefficient is close to zero and substantially smaller than the actual estimated effect. The distribution of the coefficients follows a normal pattern, and more than 90% of the p-values are greater than 0.1. This confirms that ESG's effect on GT is not driven by chance factors, indicating no major omitted variables in our baseline model.



Note: Figure 1 plots the Kernel density and p-values of 500 estimates about the coefficients of *ESG*. The left graph shows the mean and P-value distribution of the coefficients of "pseudo ESG variables" on enterprise CEI, while the right graph shows the mean and P-value distribution of the coefficients of "pseudo ESG variables" on enterprise TFP.

Figure 1. Placebo test

[5] including Hebei, Henan, Jiangsu, Shandong, Hunan, Sichuan, Chongqing, Guizhou, Hainan, Guangxi, Shanxi and Beijing.

4.3. Government environmental policy implementation: the impact of ESG advantages on GT

4.3.1. Baseline results

The results in Columns (1)–(2) of Table 9 report the differences in the impact of ESG advantages on enterprise CEI and TFP before and after the implementation of the *new EPL*. The results show that the coefficients of *Treat*×*Time1* are –0.0590 and 0.0666 respectively, and pass the significance test at the 1% level, indicating that after the implementation of the *new EPL*, compared with enterprises without ESG advantages, enterprises with ESG advantages have significantly enhanced their degree of GT. The results in Columns (3)–(4) of Table 9 report the differences in the impact of ESG advantages on GT before and after the implementation of the *EPTL*. The results show that the coefficients of *Treat*×*Time2* are significantly negative and positive respectively, indicating that compared with before policy implementation, the promotion effect of ESG advantages on corporate GT has significantly increased after the implementation of the *EPTL*. This is because environmental policies increase the pressure for enterprises to manage their environment, thus prompting enterprises with ESG advantages to play a more active role and carry out GT.

Table 9. The impact of ESG on GT after the implementation of environmental policies

	CEI	*TFP_lp*	*CEI*	*TFP_lp*
	(1)	(2)	(3)	(4)
Treat×*Time1*	–0.0590***	0.0666***		
	(0.0176)	(0.0224)		
Treat×*Time2*			–0.0639***	0.0551***
			(0.0189)	(0.0189)
Treat	0.0214	0.0073	0.0054	0.0305**
	(0.0142)	(0.0204)	(0.0115)	(0.0144)
Constant	–0.2365*	–2.7450***	–0.2428*	–2.7445***
	(0.1435)	(0.1542)	(0.1434)	(0.1541)
Controls	Yes	Yes	Yes	Yes
Province/Industry/Year FE	Yes	Yes	Yes	Yes
Observations	8,943	9,479	8,943	9,479
Adj_R^2	0.0326	0.8217	0.0331	0.8217

Note: In the actual regression, the effect of the individual term (Time) of the interaction variable on the explained variable was absorbed by more refined industry fixed effects and year fixed effects, so there is no corresponding report in the results table.

4.3.2. Parallel trend tests and placebo tests

We adopt the event study method to conduct parallel trend and dynamic effect tests, following the approach of Deschenes et al. (2017). Figure 2 shows the results of the parallel trend test before and after the implementation of the *new EPL*. We select the year before policy implementation (2014) as the base period. Before the implementation of the *new EPL*, the confidence intervals of the estimated coefficients of the interaction term *Treat* × *Time1*

contain 0, indicating that the parallel trend assumption of the DID analysis is satisfied. This suggests that there is no significant difference in the trend of GT changes between the two types of companies, regardless of their ESG advantages. Furthermore, from the results of dynamic effects, in most years after the implementation of the *new EPL*, companies with ESG advantages show a significantly higher increase in GT compared to other companies, demonstrating a long-term stable effect. The parallel trend test results before and after the implementation of the *EPTL* are shown in Figure 3. We selected the year before the policy was implemented (2017) as the base period. The interaction term *Treat×Time2* is not statistically significant, indicating no systematic difference in the level of GT between enterprises with and without ESG advantages prior to the implementation of the *EPTL*. This supports the parallel trends assumption. In addition, taking the CEI of enterprises as an example, we conduct a placebo test on the *Treat×Time1* interaction term by randomly sampling 500 times. From the Figure 4, we can see that the 500 estimated regression coefficients are concentrated around 0 and follow a normal distribution, which is consistent with the expectations of the placebo test. The results in Table 9 further support Hypothesis 1.

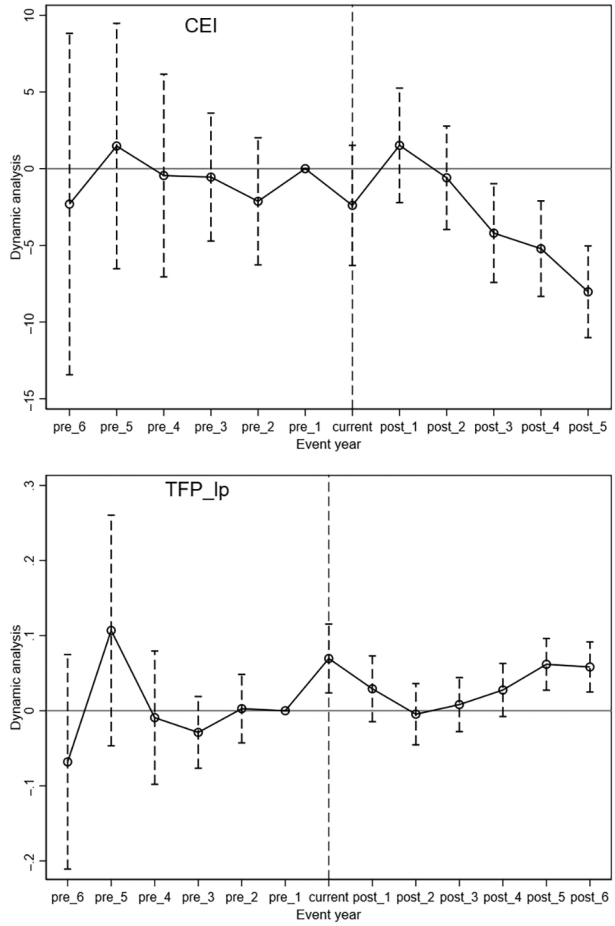
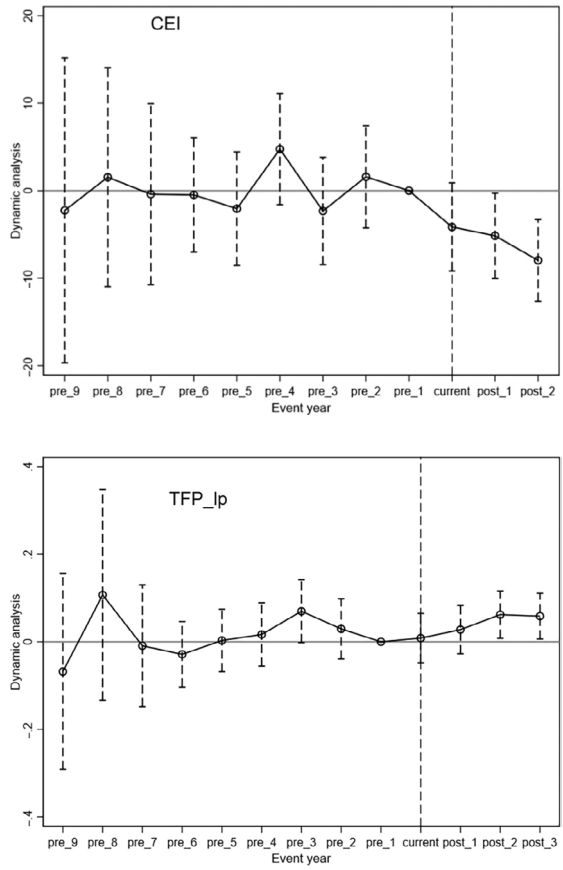
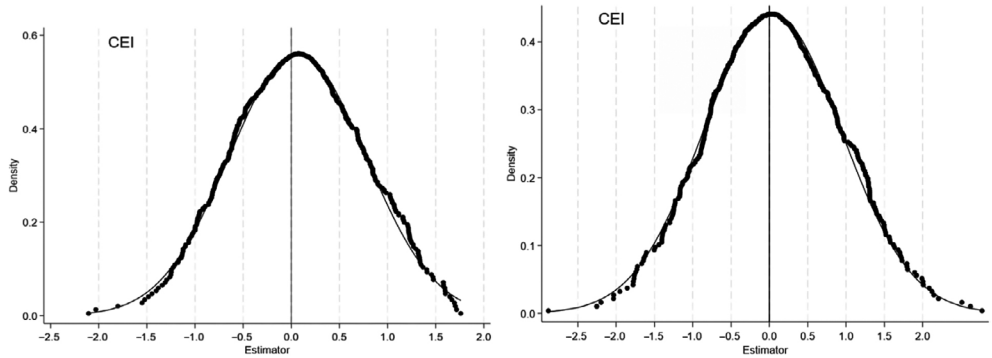


Figure 2. Parallel trend and dynamic effect test (the *new EPL*)



Note: Figure 3 plots the dynamic effects of ESG advantages on corporate GT. The coefficient estimates and the 95% confidence intervals are based on the results from Table 9.

Figure 3. Parallel trend and dynamic effect test (the *EPTL*)



Note: The left and right sides of Figure 4 show the results of the placebo test for the implementation of the new EPL and the EPTL policy, respectively.

Figure 4. Placebo test

4.4. Channel analysis

By establishing a comprehensive ESG information disclosure mechanism, firms can effectively address the dual market failures associated with GT. In terms of information, standardized ESG disclosure lowers investor evaluation costs related to green technologies and emission reduction performance. This mitigates information asymmetry through signaling effects, enabling firms with strong green competitiveness to gain capital market recognition and achieve a green premium. From a financing perspective, integrating ESG as a non-financial risk metric into credit rating systems expands access to green financing channels – such as green bonds and sustainability-linked loans – while reducing financing costs and alleviating liquidity constraints. This dual mechanism reshapes market incentives, encouraging SMEs and traditional industries to participate in green supply chains. It also helps rebalance the current structural reliance on policy-driven initiatives and leading firms, ultimately enabling Pareto-improving resource reallocation through market forces. This study examines three mechanisms through which ESG facilitates corporate GT: improved financing conditions, optimized environmental governance, and enhanced information transparency.

4.4.1. Improved financing environment

Strong ESG performance enhances corporate value, reduces financial risk, and builds investor trust. Evidence indicates that ESG practices can improve corporate financing conditions, thereby supporting GT. Specifically, ESG helps lower financing costs, eases credit constraints, and improves loan compliance. These advantages enable firms to secure more external funding for sustainable development initiatives. To verify this hypothesis, we have constructed the following Model (4):

$$FE_{it} = \alpha + \alpha_1 ESG_{it} + \gamma X_{it} + v_t + \eta_j + \varphi_p + \varepsilon_{it}, \tag{4}$$

where FE_{it} includes the following variables: (1) internal financing environment (*Cflow*), measured by corporate cash flow; (2) debt financing cost (*DebtCost*), measured by the proportion of interest expenditure to total liabilities; (3) equity financing cost (*EquityCost*); (4) long-term loan (*Lloan*), measured by the natural logarithm of long-term loans plus one; (5) financing constraints, measured by the SA index and KZ index. The remaining variables are consistent with Eq. (1).

As shown in Column (1) of Table 10, the coefficient of *ESG* is significantly positive, indicating that ESG significantly enhances corporate cash flow management and improves the internal financing environment. Columns (2)–(3) report the results for corporate financing costs. The coefficients of *ESG* are all significant and negative, suggesting that ESG significantly reduce the cost of corporate finance. Column (4) reports the results for corporate loans. The coefficient of *ESG* is significantly positive, indicating that ESG can improve long-term lending for companies. In addition, the coefficients of *ESG* are negative and significant in Columns (5)–(6), indicating that ESG can ease financial constraints. Overall, these results suggest that ESG can drive the GT of enterprises by improving the financing environment.

Table 10. Channel analysis: improved financing environment

	Cflow	*DebtCost*	*EquityCost*	*Lloan*	*SA*	*KZ*
	(1)	(2)	(3)	(4)	(5)	(6)
ESG	0.0025***	–0.0004***	–0.0010***	0.1812***	–0.0023***	–0.0832***
	(0.0006)	(0.0001)	(0.0003)	(0.0515)	(0.0009)	(0.0121)
Constant	–0.0101	–0.0265***	0.0806***	–67.8496***	21.7131***	2.5283***
	(0.0203)	(0.0027)	(0.0071)	(1.3073)	(0.0323)	(0.3508)
Province/Industry/Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,075	21,075	21,075	21,075	21,075	21,075
Adj_R^2	0.1296	0.2685	0.0438	0.4524	0.9932	0.4937

Notes: The calculation formula is: $EquityCost = \sqrt{(eps2 - eps1)/p0}$, where $p0$ is the current stock price at the end of the period, *eps*1 is the forecast value of earnings per share after one year, and *eps*2 is the forecast value of earnings per share after two years. $SA = -0.737 * size + 0.043 * size \wedge 2 - 0.04 * age$, where *size* is the natural logarithm of the total assets of the enterprise, and *age* is the age of the establishment of the enterprise, measured by the difference between the observed year and the establishment year. The absolute value of the SA index was taken, and the larger the SA index, the higher the financing constraints.

4.4.2. Optimized environmental governance strategy

We believe that ESG can improve a company's own environmental governance strategies at the behavioral level. Specifically, ESG not only achieves conceptual governance, but also facilitates the implementation of end-of-pipe and source-based governance. To verify this hypothesis, we have constructed the following Model (5):

$$Envir\_strategy_{it} = \alpha + \alpha_1 ESG_{it} + \gamma X_{it} + v_t + \eta_j + \varphi_p + \varepsilon_{it}, \quad (5)$$

where $Envir\_strategy_{it}$ includes the following variables: (1) corporate management's environmental awareness. (*Envir_concept*). We used text analysis to calculate the frequency of environmental protection-related words in the MD&A section of annual reports. Specifically, we measured the proportion of total words that were related to environmental protection and governance. This allowed us to gauge the level of environmental awareness among corporate management; (2) the level of investment in green and environmental protection (*Envir_cost*), measured by the scale of green and environmental protection investment in enterprises; (3) We use the number of independent applications (*Ginno*) (joint applications: *Ginno_un*) for green patents and the number of independent applications (*Ginno_inven*) (joint applications: *Ginno_inven_un*) for green invention patents of enterprises as our measures.

As shown in Column (1) of Table 11, the coefficient of *ESG* is significantly positive, indicating that ESG significantly enhance the environmental mindset of corporate management. Columns (2) report the results for corporate environmental investments. The coefficients of *ESG* are all significant and positive, suggesting that ESG significantly enhances the level of investment in green and environmental protection. In addition, the coefficients of *ESG* are positive and significant in Columns (3)–(6), further indicate that ESG increased the level of green innovation in enterprises. Overall, the evidence indicates that ESG promotes GT of enterprises by optimizing their environmental governance strategies.

Table 11. Channel analysis: Optimized environmental governance strategy

	Envir_concept	*Envir_cost*	*Ginno*	*Ginno_inven*	*Ginno_un*	*Ginno_inven_un*
	(1)	(2)	(3)	(4)	(5)	(6)
ESG	0.2574***	0.0698**	0.4510***	0.3486***	0.6042***	0.5402***
	(0.0709)	(0.0298)	(0.0985)	(0.0697)	(0.1911)	(0.1516)
Constant	–8.7000***	–4.0065***	–48.2467***	–31.6785***	–73.5066***	–46.0620***
	(0.8975)	(0.6791)	(6.3104)	(4.1451)	(8.7789)	(5.8184)
Province/ Industry/Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,075	21,075	21,075	21,075	21,075	21,075
Adj_R^2	0.0740	0.0959	0.0957	0.0948	0.2436	0.2578

4.4.3. Enhanced the information environment

We believe that ESG can attract more analysts to monitor companies, reduce information gaps between management and stakeholders, improve environmental disclosure quality, and strengthen corporate governance for environmental management. This enhances transparency with capital markets, helps prevent short-term managerial decisions, lowers agency costs, and ultimately motivates management to pursue GT. To verify this hypothesis, we have constructed the Model (6):

$$Information_{it} = \alpha + \alpha_1 ESG_{it} + \gamma X_{it} + v_t + \eta_j + \varphi_p + \varepsilon_{it}, \quad (6)$$

where $Information_{it}$ includes the following variables: first, analyst coverage serves as a proxy for information asymmetry, calculated as the number of analysts following the company (*Analysts*). Second, environmental disclosure intensity (*EMD*) tallies the annual instances of a company reporting on topics such as environmental philosophy, goals, management systems, training, action plans, emergency responses, awards, and the "Three Simultaneities" system. Third, environmental management governance institutions completeness (*Green_governance*). We define the improvement level of a company's environmental governance mechanisms based on whether the company discloses information about its "environmental management organizational structure" in its environmental report or corporate social responsibility report. If such information is disclosed, then *Green_governance* is assigned a value of 1; otherwise, it is assigned a value of 0. Fourth, the extent of short-sightedness of management (*Myopia*). We measure corporate management short-sightedness using short-term word frequency in MD&A texts. Higher frequency indicates shorter decision-making horizons.

The results are summarized in Table 12. The coefficients of *ESG* are positive and significant in Columns (1)–(3), further indicate that ESG can improve the information environment. Column (4) reports the result for *Myopia*. The coefficient of *ESG* is significant and negative, suggesting that ESG significantly reduces the extent of short-sightedness of management. Overall, the evidence indicates that ESG promotes GT by enhancing the information environment.

Table 12. Channel analysis: Reduced information asymmetry

	Analysts	*EMD*	*Green_governance*	*Myopia*
	(1)	(2)	(3)	(4)
ESG	0.8834***	1.2030***	0.0020***	–0.0015***
	(0.0562)	(0.0385)	(0.0007)	(0.0005)
Constant	–79.2073***	–25.3604***	–0.0722***	0.1623***
	(1.6428)	(0.9579)	(0.0147)	(0.0151)
Province/Industry/Year FE	Yes	Yes	Yes	Yes
Observations	21,075	21,075	21,075	21,075
Adj_R^2	0.3517	0.3806	0.0419	0.1128

5. Extension analysis

5.1. Heterogeneity analysis

5.1.1. Availability of green credit for enterprises

We use a dummy variable to indicate whether a company has obtained green credit in that year (*GLoan* = 1 if it has, *GLoan* = 0 if it hasn't). The results are shown in Columns (1)–(4) of Table 13. The results show that within the group of companies that have not obtained green credit, the coefficient of *ESG* is more significant. Meanwhile, the test for differences between groups remains significant, indicating that the promoting effect of ESG on corporate GT is more pronounced in companies without green credit support.

5.1.2. Greenwashing degree of enterprises

According to the annual median of corporate greenwashing degree, we grouped samples and the results are shown in Columns (5)–(8) of Table 13. The results show that when the explained variable is CEI, the coefficient of ESG is negative and more significant in the high greenwashing degree enterprise group, indicating that the inhibitory effect of ESG on CEI is more obvious in high greenwashing degree enterprises. When the explained variable is TFP, the coefficients of *ESG* are all significantly positive and there is no significant difference between groups, indicating that there is no difference in the promoting effect of ESG on corporate CEI among different groups.

5.2. The impact of ESG sub-items on corporate GT

Since ESG combines environmental, social, and governance factors, we examine which most drive GT. To test this, we replace the baseline model's ESG variable with separate *E*, *S*, and *G* ratings. The results are presented in Table 14. Results show significant positive coefficients for E-rating, S-rating, and G-rating, confirming that environmental, social, and governance factors all boost corporate GT. Crucially, S-rating's larger coefficient compared to E-rating and G-rating reveals social responsibility as the strongest driver of GT. One possible explanation for this is that corporate social responsibility encompasses not only environmental responsibilities but also responsibilities towards employees, communities, and society.

Table 13. Heterogeneity analysis

	CEI	*CEI*	*TFP_lp*	*TFP_lp*	*CEI*	*CEI*	*TFP_lp*	*TFP_lp*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESG	–0.0264	–0.0283***	0.0190*	0.0227***	–0.0226***	–0.0171*	0.0260***	0.0261***
	(0.0200)	(0.0060)	(0.0106)	(0.0036)	(0.0070)	(0.0097)	(0.0045)	(0.0059)
Constant	–1.3687**	–0.2840*	–2.8333***	–3.1232***	–0.0679	–1.0277***	–3.1526***	–3.4470***
	(0.6557)	(0.1667)	(0.4070)	(0.1147)	(0.1835)	(0.3036)	(0.1462)	(0.1853)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province/ Industry/ Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,661	18,869	1,661	18,869	14,075	6,396	14,075	6,396
Adj_R^2	0.0659	0.0695	0.8027	0.7726	0.0617	0.0911	0.7226	0.8316
Bdiff	–0.0019***(0.000)		0.0037***(0.000)		0.0055***(0.000)		0.0001(0.480)	

Notes: (i) Availability of green credit for enterprises: Based on the classification of green projects outlined in the 2013 "Guidelines for Filling in Green Credit Statistics Form" (formerly China Banking Regulatory Commission), we employed text analysis of corporate loan announcements and annual reports to determine whether bank credit obtained by a company qualifies as green credit. (ii) A scoring system was developed via text analysis of corporate environmental and social responsibility reports. This system evaluates greenwashing across three dimensions – governance & structure, processes & controls, and inputs & outputs – comprising 16 total items. Greenwashing is defined through two behaviors: selective disclosure of environmental issues (*Gwls*) and expressive manipulation aimed at creating a strategically positive image (*Gwle*) The degree of greenwashing (*Gwl*) is defined as: $Gwl = \sqrt{Gwls * Gwle}$.

Thus, companies pursuing GT should consider these factors to enhance their social image. In contrast, environmental ratings focus mainly on eco-friendly actions and outcomes, while governance ratings address management structures. Though these factors also affect GT, their impact is generally smaller than social responsibility's influence.

Table 14. The impact of ESG sub-items on corporate GT

	CEI	*CEI*	*CEI*	*TFP_lp*	*TFP_lp*	*TFP_lp*
	(1)	(2)	(3)	(4)	(5)	(6)
Erating	–0.0150***			0.0085***		
	(0.0053)			(0.0033)		
Srating		–0.0250***			0.0272***	
		(0.0053)			(0.0034)	
Grating			–0.0158***			0.0172***
			(0.0045)			(0.0029)
Constant	–0.3221**	–0.3138**	–0.2403	–3.1867***	–3.1680***	–3.2479***
	(0.1528)	(0.1519)	(0.1523)	(0.1131)	(0.1117)	(0.1126)
Province/ Industry/Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,075	21,075	21,075	21,075	21,075	21,075
Adj_R^2	0.0676	0.0682	0.0678	0.7688	0.7694	0.7691

5.3. The impact of ESG uncertainty on corporate GT

ESG disclosure serves as a key channel for listed companies to demonstrate social responsibility and offers critical input for investors assessing long-term corporate value and risks. However, the absence of consistent standards and regulatory oversight poses challenges. First, without uniform disclosure rules, companies adopt divergent reporting approaches, making it difficult to accurately compare ESG performance across firms. This may also incentivize some firms to overstate their ESG achievements to attract investment. Second, in the absence of market supervision, rating agencies can be misled, leading to inconsistent or biased evaluations. This not only undermines rating fairness and accuracy but also heightens investor uncertainty regarding ESG ratings. A key question thus arises: Does the promoting effect of ESG on corporate GT depend on the level of such uncertainty? To explore this, we develop the following Model (7) for further analysis.

$$GT_{it} = \alpha + \alpha_1 ESG \times Uncertainty_{it} + \alpha_2 ESG_{it} + \alpha_3 Uncertainty_{it} + \gamma X_{it} + \lambda_i + v_t + \eta_j + \varphi_p + \varepsilon_{it}. \quad (7)$$

We have constructed the ESG Uncertainty indicator by using six ESG rating data from *Huazheng*, *Bloomberg*, *SynTao Green Finance*, *FTSE Russell*, *Wind*, and *Alliance Rating Agency*. To address variations in scope and size across ESG rating datasets while preserving sample size, we follow the methodology of Avramov et al. (2022). The procedure involves three steps: first, identifying publicly listed firms present in two rating databases and determining their annual percentile ranks within the combined annual sample; second, calculating the standard deviation of these percentile ranks for each firm between the two raters; and finally, repeating this process for all 15 unique pairs derived from six rating sets. The average of these cross-rater standard deviations constitutes our measure of ESG Uncertainty (*Uncertainty*). The results in Table 15 show that when the explained variable is *CEI*, the coefficient of *ESG*Uncertainty* is negative but not significant. When the explained variable is *TFP*, the coefficient of *ESG*Uncertainty* is significantly negative, indicating that ESG uncertainty will weaken the promotion effect of ESG on the GT of enterprises.

Table 15. The impact of ESG uncertainty on corporate GT

	CEI	*CEI*	*TFP_lp*	*TFP_lp*
	(1)	(2)	(3)	(4)
*ESG*Uncertainty*	–0.0524	–0.0516	–0.0601***	–0.0494***
	(0.0337)	(0.0335)	(0.0194)	(0.0152)
ESG	0.0072	0.0045	0.0507***	0.0159***
	(0.0088)	(0.0088)	(0.0053)	(0.0041)
Uncertainty	0.2496*	0.2278	0.3077***	0.1907***
	(0.1505)	(0.1498)	(0.0877)	(0.0680)
Constant	1.3479***	–0.6750*	8.0339***	–2.8321***
	(0.0364)	(0.3646)	(0.0223)	(0.2650)
Firm FE	Yes	Yes	Yes	Yes
Province/Industry/Year FE	Yes	Yes	Yes	Yes
Observations	21,075	21,075	21,075	21,075
Adj_R^2	0.2273	0.2304	0.8630	0.9128

5.4. Identification and analysis of spillover effect of ESG emission reduction

In the context of sustainable development, corporate emission-reduction decisions often exhibit patterns of mutual imitation and learning. Such behavior affects not only individual firms' carbon emissions but also disseminates emission-reduction practices across industry peers. Specifically, when leading firms adopt low-carbon business strategies driven by ESG considerations, competitors are likely to emulate these actions to maintain relative progress and market position. To examine this, Model (8) tests the impact of ESG on industry-wide carbon emissions. Furthermore, Model (9) analyzes how the interaction between industry-level ESG and peer-firm carbon emissions affects corporate CEI, thereby investigating the within-industry contagion mechanism of ESG spillover effects.

$$Cmiss\_ind_{j,t+1} = \alpha + \alpha_1 ESG_{i,t} + \gamma X_{i,t} + \lambda_i + v_t + \eta_j + \varphi_p + \varepsilon_{i,t}; \quad (8)$$

$$CEI_{i,t+1} = \alpha + \alpha_1 Cmiss\_se_{j,t} + \gamma X_{i,t} + \lambda_i + v_t + \eta_j + \varphi_p + \varepsilon_{i,t}, \quad (9)$$

where $Cmiss\_ind_{j,t+1}$ is the total amount of carbon dioxide emissions from industry j in year $t + 1$. ESG_{it} is the ESG rating of enterprise i in year t. $CEI_{i,t+1}$ is the CEI of enterprise i in year $t + 1$. $Cmiss\_se_{j,t}$ is the product of ESG at the industry level ($ESG\_ind_{j,t}$) and carbon emissions of other enterprises in the industry ($PCmiss_{j,t}$) measures the interaction effect of ESG and carbon emissions of other enterprises in industry j on enterprise i in year t. $ESG\_ind_{j,t}$ represents the ESG indicators at the industry level. The calculation method is to differentiate the ESG of in various industries and then calculate the weighted average based on the total assets of enterprises. $PCmiss_{j,t}$ represents the weighted average of carbon emissions of other enterprises calculated based on the total assets of each enterprise in the same industry j after excluding the sample enterprises in year t.

As shown in Column (1) of Table 16, the coefficient of *ESG* is significantly negative, indicating that ESG can help promote industry carbon emission reduction to a certain extent, resulting in spillover effects of micro-enterprise carbon emission reduction governance on the industry. The coefficient of *Cmiss_se* in Column (2) is significantly negative, indicating that the interaction between ESG and carbon emission reduction behaviors of other enterprises within the same industry will drive micro-enterprises to adjust their carbon emission decisions, resulting in a peer effect. This also indicates to some extent that the governance effect of ESG on micro-enterprises' emission reduction can be transmitted through the peer effect and further strengthened under the influence of other enterprises' emission reduction efforts.

In different levels of competition, the spillover transmission effect between enterprises may vary. Therefore, we further differentiate the degree of industrial competition to explore whether the spillover effect of ESG on corporate carbon reduction is different under different levels of competition. We use the Herfindahl-Hirschman Index (HHI) to differentiate the level of competition among industries. Specifically, if the annual HHI of an industry is higher than the annual median, it is classified into the low-competition industry group; otherwise, it is classified into the high-competition industry group. The estimated results are shown in Column (3)–(4) of Table 16. The results show that the coefficient of *Cmiss_se* is significantly negative in the high-competition industry sample group and not significant in the low-competition industry sample group. This indicates that under conditions of intense competition, corporate carbon emissions are more likely to be affected by ESG spillovers through peer effects conduction.

Table 16. The spillover effect and heterogeneity analysis

	Cmiss_ind	*CEI*	*CEI*	*CEI*
	(1)	(2)	(3)	(4)
ESG	–1.14115**			
	(0.4958)			
Cmiss_se		–0.00010**	–0.00000	–0.00021**
		(0.0000)	(0.0001)	(0.0001)
Constant	87.40722***	–0.87810**	–0.10790	–1.89859***
	(31.9320)	(0.4309)	(0.6563)	(0.6998)
Firm FE	Yes	Yes	Yes	Yes
Province/Industry/Year FE	Yes	Yes	Yes	Yes
Observations	18,352	10,663	9,124	9,228
Adj_R^2	0.84709	0.23483	0.24297	0.21263

6. Discussion and conclusions

6.1. Discussion

This study advances the growing research on corporate GT by revealing the various roles of ESG practices. Our findings differ from but also build on previous studies, providing deeper insights into GT drivers and mechanisms that go beyond traditional regulations.

Firstly, ESG serves as a dual-pronged driver of GT, complementing formal regulations as an informal mechanism and acting as a market-driven enabler through peer effects, thereby challenging the prevailing regulatory-centric paradigm exemplified by Weber and Neuhoff (2010), Du et al. (2021), and Zeng et al. (2023). Extant research predominantly positions formal environmental regulations as the cornerstone of GT (Chen et al., 2023a; Du et al., 2021; Lu et al., 2022; Weber & Neuhoff, 2010; Zeng et al., 2023). These studies compellingly demonstrate how policies like emissions trading, green credit guidelines, or environmental inspections drive corporate environmental action, often through compliance pressure or resource allocation mechanisms. This regulatory-centric view aligns with the broader literature on environmental policy instruments (Ambec et al., 2013; Porter & Van der Linde, 1995), emphasizing command-and-control or market-based tools. While acknowledging the critical importance of formal regulation, our results reveal a more complex and proactive dynamic. We demonstrate that ESG functions not merely as an informal regulatory mechanism (complementing formal laws like the *EPTL* akin to the "civil regulation" discussed by Gunningham et al., 2004), but also as a potent market-driven enabler of proactive GT, driven by stakeholder pressures and competitive advantages (Freeman, 1984; McWilliams & Siegel, 2001). Crucially, we identify peer effects (Testa et al., 2011) as a significant channel through which ESG fosters GT, a dimension largely underexplored within the dominant policy-centric frameworks (Weber & Neuhoff, 2010; Zeng et al., 2023). This challenges the conventional paradigm that views GT as primarily reliant on government mandates and underscores the vital, complementary role of corporate self-regulation and market dynamics facilitated by ESG within a multi-faceted governance system.

Secondly, our study bridges a critical gap by demonstrating how ESG addresses persistent barriers to GT – specifically financing constraints and information asymmetry – through enhancing firm value, reducing financing costs, attracting capital (extending Tan & Zhu, 2022), and signaling corporate sustainability commitment to stakeholders and markets (contrasting with Lins et al., 2017; Avramov et al., 2022). Prior study has often implicitly or explicitly acknowledged financing constraints and information asymmetry as significant barriers to GT, particularly for resource-intensive green investments (e.g., Lu et al. (2022) highlight green finance policy increasing constraints for polluters as a stick; hen et al. (2023a) note regional financial disparities impacting green finance effectiveness). Studies like Hall (2002), Hottenrott and Peters (2012) broadly document innovation financing hurdles, while Healy and Palepu (2001) establish the pervasive challenges of information asymmetry. However, a clear gap exists in understanding how firms can proactively overcome these specific barriers within the context of GT using non-regulatory tools like ESG. Our study addresses this gap by empirically demonstrating ESG's pivotal role in mitigating these obstacles, offering a "carrot" mechanism complementary to regulatory "sticks". For one thing, we provide robust evidence that ESG significantly improves the corporate financing environment. Specifically, ESG enhances firm value, reduces perceived financial risks (supporting the risk mitigation view in Albuquerque et al., 2019), and attracts greater external capital (both debt and equity), leading to tangible benefits such as improved internal financing capacity, lower costs for both debt and equity financing (refuting or contextualizing findings like Saygili et al. (2022) in an emerging GT context), and increased access to long-term loans and specialized green credit (Tan & Zhu, 2022). This result aligns with and extends the work of Tan and Zhu (2022), who link ESG to eased financial constraints driving green innovation, by detailing the specific financing channels impacted and demonstrating its effect in facilitating GT beyond innovation alone. For another thing, moving beyond studies primarily linking ESG to firm value or risk in specific contexts (e.g., Lins et al. (2017) on crisis resilience; Reber et al. (2022) on IPO risk; Pástor et al. (2021) on equilibrium returns), we explicitly integrate Stakeholder Theory (Freeman, 1984) and Signaling Theory (Connelly et al., 2011) to explain how ESG mitigates information asymmetry specifically in the context of GT. Our results show that strong ESG performance acts as a credible signal of managerial quality and commitment to sustainability (Flammer, 2015), attracting greater analyst coverage (enhancing market scrutiny and information flow) and significantly improving the quality and quantity of environmental disclosures (meeting stakeholder demands as in Clarkson et al. (2008)). This mechanism, empirically demonstrated through these specific metrics, offers a clearer view of how ESG facilitates efficient resource allocation for GT, differing from the broader financial performance or risk focus of studies like Saygili et al. (2022) or Avramov et al. (2022). Taken together, this provides a more holistic understanding of ESG's function in greening corporate finance by tackling core market imperfections.

Finally, ESG functions as a proactive catalyst for low-carbon investment even absent stringent regulation, incentivized by improved financing access and reduced information asymmetry, while underscoring the policy imperative for standardized disclosure frameworks (supporting Avramov et al. (2022)) to amplify ESG's market-driven pathway toward climate goals. Tan and Zhu (2022) established a valuable link between ESG, eased financial constraints, and corporate green innovation. Our results confirm and provide context for this relationship,

demonstrating that strong ESG performance enhances access to green credit. This outcome aligns with the policy intent behind initiatives like China's green credit guidelines (Lu et al., 2022), yet it is driven by market forces. We extend this understanding significantly by demonstrating that the ESG-induced improvements in the financing environment and reduction in information asymmetry documented in our study serve as a powerful proactive incentive for firms to invest in low-carbon projects and practices, even in the absence of immediate, stringent regulatory pressure. This positions ESG as a crucial market-based catalyst for decarbonization, operating alongside (and sometimes preceding) formal regulation, driven by investor preferences (Pástor et al., 2021) and the pursuit of competitive advantage through sustainability (Porter & Kramer, 2006). Furthermore, our results strongly reinforce the critical need for standardized and reliable ESG disclosure frameworks – a point underscored by Avramov et al. (2022) regarding rating uncertainty and its market consequences. Our results emphasize that such standardization is fundamental not only for investor decision-making but crucially for reducing the information asymmetry that hinders efficient capital allocation towards GT and enhancing the credibility and effectiveness of ESG as a market signal. Standardized disclosures (e.g., aligned with frameworks like TCFD, SASB, or emerging ISSB standards) empower investors to make more informed decisions, improving market efficiency, bolstering investor confidence in green investments, and ultimately strengthening the market-driven pathway to GT that our study identifies. This policy imperative is vital for scaling the impact of ESG globally (Eccles & Serafeim, 2013) and achieving climate goals outlined in agreements like the Paris Agreement.

6.2. Conclusions

Corporate GT is crucial for both national economic growth and enterprise development, making the transition to a green economy a global priority. As sustainable development gains wider acceptance, the role of ESG disclosure in driving corporate GT has attracted significant attention. Our results indicate that ESG significantly reduces CEI and improves TFP. After IV estimation, PSM, Heckman two-stage estimation, replacing variables, eliminating interference from other policies in the same period, and placebo tests, the baseline results remain unchanged. Channel analysis shows that ESG improves the financing environment, optimizes environmental governance strategies, and improves the information environment, thereby promoting corporate GT. Compared with enterprises without ESG advantages, those with ESG advantages show significant improvement in GT after the implementation of the *new EPL* and the *EPTL*, indicating that increased environmental regulation pressure enhances the role played by ESG advantages. We also find that ESG has a stronger positive effect on companies with limited access to green credit and those where greenwashing is common. Finally, when examining the three ESG factors separately, social responsibility shows the most significant impact on promoting GT. In addition, ESG uncertainty can weaken the promotion effect of ESG on the GT. Our industry analysis shows that ESG practices help reduce emissions across sectors and create peer effects, where companies influence each other's carbon decisions. When industry competition is stronger, a firm's carbon emissions level tends to be more

strongly affected by both its own ESG performance and the carbon behaviors of other industry players. Overall, our study contributes new empirical evidence on ESG's environmental impacts and offers valuable insights for global low-carbon transition strategies.

Our results illuminate pathways to promote corporate GT. First, governments and regulatory bodies should actively encourage firms to embrace and integrate ESG practices. Given their efficacy in reducing CEI and boosting productivity, incentives for ESG adoption could accelerate progress towards sustainable business operations. Second, our study reveals that heightened environmental regulation amplifies the positive impact of ESG practices. Policymakers are thus advised to contemplate the introduction of more stringent environmental regulations, serving as a catalyst for deeper corporate GT integration. Third, policymakers should address this issue by developing mechanisms to detect and penalize greenwashing practices. Fourth, we indicate that social responsibility has the greatest effect in enhancing GT. Governments and regulatory bodies should encourage companies to prioritize social responsibility in their ESG efforts. Fifth, our findings indicate that ESG uncertainty may reduce the positive impact of ESG on GT. Therefore, policymakers should focus on reducing this uncertainty by establishing clear ESG reporting guidelines and standards.

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Author contributions

Xubing Fang: Writing – review & editing; project administration, investigation, methodology, supervision. Maotao Liu: writing – review & editing; data curation; funding acquisition.

Disclosure statement

The authors declare no competing interests.

Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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