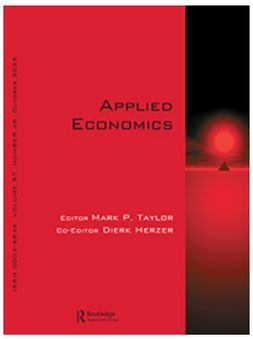

Applied Economics

ISSN: 0003-6846 (Print) 1466-4283 (Online) Journal homepage: www.tandfonline.com/journals/raec20

Does ESG performance promote 'New Quality Productive Forces' in China? From efficiency-driven and innovation-driven perspectives

Siqi Li & Yangkai Jin

To cite this article: Siqi Li & Yangkai Jin (05 Oct 2025): Does ESG performance promote 'New Quality Productive Forces' in China? From efficiency-driven and innovation-driven perspectives, Applied Economics, DOI: 10.1080/00036846.2025.2567583

To link to this article: https://doi.org/10.1080/00036846.2025.2567583

Published online: 05 Oct 2025.

APPLIED ECONOMICS
https://doi.org/10.1080/00036846.2025.2567583

Routledge
Taylor & Francis Group

Does ESG performance promote 'New Quality Productive Forces' in China? From efficiency-driven and innovation-driven perspectives

Siqi Li and Yangkai Jin

China Institute for WTO Studies, University of International Business and Economics, Beijing, China

ABSTRACT

With the rapid advancement of corporate Environmental, Social, and Governance (ESG) ratings, it is crucial to examine their effects on China's pursuit of 'New Quality Productive Forces' from both efficiency-driven and innovation-driven perspectives. By utilizing panel data from Chinese listed firms from 2009 to 2023, our empirical results indicate that ESG ratings significantly enhance both total factor productivity (TFP) and the quantity and quality of green innovation, with the effect on green innovation being more pronounced. This positive effect is achieved through multiple mechanisms, including the alleviation of financing constraints and the mitigation of principal-agent issues. Additionally, media attention serves as a positive moderating factor, strengthening the beneficial impact of ESG ratings on both TFP and green innovation. We also explore the impact of ESG ratings on corporate greenwashing and find that higher ESG ratings substantially lower the likelihood of greenwashing. Heterogeneity analyses reveal that the impact of ESG ratings varies across different regional policy environments, industry sectors, and firm characteristics. Notably, the positive effects on TFP and green innovation are more pronounced in regions with Pilot Free Trade Zones (PFTZs) and firms in technology-intensive and capital-intensive sectors, with the magnitude of these effects also being influenced by ownership structure.

KEYWORDS

ESG; Total factor productivity; Green innovation; New Quality Productive Forces; Chinese listed firms

JEL CLASSIFICATION

D24; M14; O30

I. Introduction

Within the context of global sustainable development, the Environmental, Social, and Governance (ESG) concept has profoundly reshaped the landscape of responsible investment. Recognized as key non-financial indicators, ESG ratings provide essential insights into corporate sustainability on a worldwide scale.

ESG ratings have become central to guiding corporate behaviour, playing a crucial role in enhancing productivity and innovation by offering a comprehensive framework for assessing sustainability and operational efficiency. This framework helps firms manage risks and identify opportunities related to ESG practices, which, in turn, influence their productivity and innovation capabilities.

In the context of China's pursuit of high-quality economic growth, understanding the linkage between ESG ratings and productivity becomes particularly pertinent. The sustainable development principles embodied in ESG practices align closely with the Chinese concept of 'New Quality Productive Forces'. Introduced in September 2023 and reaffirmed in subsequent political sessions,[1] this concept emphasizes productivity advancements rooted in high technology, efficiency, and quality, with a focus on sustainable growth and reduced reliance on resource-intensive practices.[2] Accordingly, we examine ESG ratings within the Chinese economic context and explore the associated theoretical implications of 'New Quality Productive Forces'.

On another note, the theoretical richness of 'New Quality Productive Forces' motivates us to identify core indicators and investigate the mechanisms through which ESG ratings influence them. Progression in this area requires new principles that enhance resource allocation and total factor productivity (TFP). Given that green innovation underpins high-quality growth, we

CONTACT Yangkai Jin uibejyk@163.com China Institute for WTO Studies, University of International Business and Economics, Keyan Building 504, No.10 Huixin Dongjie, Chaoyang District, Beijing 100029, China

[1]National Development and Reform Commission (NDRC), People's Republic of China. New quality productive forces. https://en.ndrc.gov.cn/news/mediaurces/202405/t20240507_1370423.html.

[2]Xinhua. Xinhua Commentary: 'New productive forces' a winning formula for China's future. https://english.news.cn/20230921/f52c169eb15e4e0da59b59c6f0c862b8/c.html.

adopt an integrated perspective of efficiency and innovation, focusing on TFP and green innovation as key components.

The body of literature on ESG ratings is rapidly evolving, offering diverse perspectives on their economic impact. One domain of research suggests ESG ratings improve corporate performance by enhancing valuation (Bofinger, Heyden, and Rock 2022; Huang 2022), reducing leverage ratios (Asimakopoulos, Asimakopoulos, and Li 2023), lowering equity capital costs (Y. Li et al. 2024), easing financial constraints (Guo et al. 2024), and managing earnings more effectively (Mao, Wang, and Lin 2024), subsequently reducing overall financial costs (Dimson, Karakaş, and Li 2015) and improving corporate financial performance (Flammer 2015; Huang 2021). Improved ESG ratings are linked to heightened productivity (X. Yu and Chen 2024), increased capital inflows (Pástor, Stambaugh, and Taylor 2021), and strengthened stakeholder trust, enhancing long-term stability (Lins, Servaes, and Tamayo 2017).

Research further examines ESG ratings' impact on corporate investment. Positive ESG ratings are associated with improved investment returns (Gehricke, Ruan, and Zhang 2024), investment efficiency (Benlemlih and Bitar 2018), anticipated profitability (Cui and Li 2024), and overall firm value (Ghoul, Guedhami, and Kim 2017). ESG ratings also influence outward foreign direct investment (Xie and Lyu 2022). However, studies indicate a negative correlation between high social performance scores and stock returns in the UK market (Brammer, Brooks, and Pavelin 2006).

The role of ESG ratings in fostering corporate innovation is well-documented, suggesting that regulatory demands for environmental sustainability propel firms to innovate, moving away from high-pollution, high-energy consumption production modalities. Evidence indicates robust ESG ratings facilitate corporate innovation by relieving financing constraints, enhancing employee innovation efficiency, and encouraging corporate risk-taking (Fang and Hu 2023).

Findings on the relationship between ESG ratings and green innovation are mixed. Some studies reveal a positive linear correlation between ESG ratings and green innovation (J. Hu, Yu, and Han 2023), while others examine their impact on both the quantity and quality of green innovation (H. Zhang, Lai, and Jie 2024). Spillover effects are also notable: improvements in downstream ESG ratings significantly motivate midstream firms to engage in green innovation (Yan, Cheng, and Wang 2024), and core firms' ESG ratings influence green innovation across industry players (J. Li, Lian, and Xu 2023). Some research suggests a U-shaped relationship in heavily polluting sectors (H. Li et al. 2022). Conversely, U.S. studies indicate that oil, gas, and energy firms – generally with lower ESG ratings and often excluded from ESG investments – are leading green patent innovators (Cohen, Gurun, and Nguyen 2020).

One strand of literature explores the relationship between ESG ratings and greenwashing. Some research has shown that discrepancies in ESG ratings might elevate greenwashing risks due to inconsistent assessments weakening external accountability (X. Hu et al. 2023). Other studies suggest that ESG ratings can effectively mitigate the risk of corporate greenwashing by reinforcing trust in sustainability disclosures (De Meyst, Cardinaels, and Van den Abbeele 2024; Ghitti, Gianfrate, and Palma 2024; W. Xu et al. 2025).

Despite advances in ESG research, there remains a gap in empirical studies examining the impact of ESG ratings in emerging markets. This article aims to address this gap through an empirical investigation in the Chinese context, employing the concept of 'New Quality Productive Forces' and focusing on TFP and green innovation as key dimensions to form a dual-dependent variable framework.

Our research design proceeds as follows: First, we identify two key dimensions – efficiency-driven and innovation-driven perspectives – relevant to 'New Quality Productive Forces' in China and incorporate them into a comprehensive empirical framework. Second, we apply a two-way fixed effects model to assess the impact of ESG ratings on these dimensions. We further conduct robustness checks to ensure the reliability of our results. Third, to mitigate endogeneity concerns, we utilize an instrumental variable within a two-stage least squares (2SLS) approach. Fourth, we develop two mediating models to examine the roles of financing constraints and principal-agent problems, as well as the moderating influence of media attention in the ESG ratings – 'New Quality Productive Forces'

relationship. Finally, we analyse how ESG ratings influence greenwashing behaviours and conduct heterogeneity tests to explore the effects across regional policy environments, industries, and firm characteristics.

Our study makes several contributions to the literature. First, it extends ESG research to the Chinese context by analysing its effects on 'New Quality Productive Forces' from efficiency-driven and innovation-driven perspectives, using TFP and green innovation as proxies. This enriches the theoretical understanding of ESG ratings' role in promoting productivity and innovation. Second, to ensure robustness amidst divergent views, we employ alternative measures of TFP and green innovation, confirming that ESG ratings positively influence both, particularly in terms of quantity and quality of green innovation. Third, we examine ESG ratings' impact on corporate greenwashing, finding that higher ESG ratings effectively reduce such behaviours. Fourth, our analysis explores mediating and moderating factors, revealing how ESG ratings serve as an information channel shaping corporate image and how media attention interacts with ESG ratings. Finally, heterogeneity analyses demonstrate how policy environments, industry sectors, and firm characteristics influence the ESG ratings-productivity-innovation relationship, enhancing the practical relevance of our findings.

The remainder of this article is organized as follows: Section II develops the research hypotheses. Section III discusses ESG ratings, TFP, and green innovation among Chinese listed firms. Section IV details the methodology, variables, and data. Section V presents baseline results and robustness checks. Section VI explores mechanisms, while Section VII offers further analyses. Section VIII concludes.

II. Research hypotheses

This study focuses on TFP and green innovation within China's 'New Quality Productive Forces', a paradigm involving efficiency-driven growth – shifting from input-based to efficiency-based models – and green innovation to integrate low-carbon attributes, fostering sustainable economic growth (Han, Zhang, and Zhao 2024; W. Liu 2024).

ESG ratings and TFP

TFP is regarded as a key measure of overall firm efficiency and productivity. Existing literature associates higher ESG ratings with improved TFP, highlighting the role of sustainable practices in firm's operations.

First, ESG ratings alleviate financing constraints by signalling social responsibility, enhancing reputation, and facilitating access to resources, subsidies, and tax incentives (Eliwa, Aboud, and Saleh 2019; X. Yu and Chen 2024). Financing constraints hinder productivity growth, with constrained firms typically showing lower productivity (Caggese 2019; Levine and Warusawitharana 2021). Thus, ESG ratings help reduce financing constraints, thereby improving TFP.

Second, ESG ratings mitigate principal-agent problems, thereby boosting TFP. The first argument pertains to reducing information asymmetry. The ESG ratings lower stakeholders' data access costs and increase transparency, helping shareholders understand financial and operational conditions and easing conflicts with managers (J. Hu, Yu, and Han 2023). The second argument focuses on strengthening oversight by improving monitoring of managerial actions (H. Li et al. 2022). The third argument involves correcting managerial myopia. ESG ratings incentivize managers to adopt a long-term view, aligning their interests with firm value and reducing short-sightedness (X. Yu and Chen 2024). By addressing agency issues, ESG ratings enhance efficiency and productivity (Biggerstaff, Cicero, and Puckett 2017), encouraging managers to prioritize sustainable development and long-term improvements in TFP.

Based on these discussions, we propose the following hypothesis:

H1: ESG ratings positively affect corporate TFP.

ESG ratings and green innovation

Recently, ESG-focused sustainable development has gained attention from governments, the public, and markets, transforming corporate green innovation.

First, ESG ratings helps firms secure financing for green innovation, which requires substantial resources over extended periods. ESG ratings reduce credit risks and build trust with financial institutions, enabling better support, especially for green projects. Firms with high ESG ratings signal sustainable growth potential, boosting investor confidence and attracting additional capital. This increased investor interest supports green innovation and the sustainable growth of firms (J. Hu, Yu, and Han 2023).

Second, ESG ratings exert external pressure, prompting governments and the public to encourage green transformations. Regulatory pressures and societal monitoring push firms to adopt green technologies, reduce pollution, and prioritize green innovation (H. Li et al. 2022).

Based on these discussions, we propose the following research hypothesis:

H2.1: ESG ratings positively affect corporate green innovation.

Furthermore, ESG ratings serve as external constraints that mitigate greenwashing risks. Studies show that ESG ratings reduce greenwashing by promoting demand for rating management and addressing principal-agent conflicts. Furthermore, the spillover effects occur as high ESG ratings reduce greenwashing risks not only within the rated firm but also among its peers within the same industry and region (W. Xu et al. 2025). Public oversight further curbs greenwashing, as stakeholder pressure discourages misleading practices (E. P. Y. Yu, Van Luu, and Chen 2020). Additionally, high ESG ratings enable firms to access policy incentives such as green finance (Fang and Hu 2023) and government subsidies, providing low-cost funding that alleviates financial barriers to green innovation.

Based on these discussions, we propose the following research hypothesis:

H2.2: ESG ratings negatively affect corporate greenwashing.

Following the above arguments, we present the following Figure 1 as the conceptual framework of our study.

III. Stylized facts

ESG practices are rapidly evolving in China and are receiving increasing attention. An increasing number of third-party organizations have started to assess and rate the ESG performance of firms. Figure 2 shows the total number of Chinese listed firms, the number of those with ESG ratings, and the proportion of ESG-rated firms from 2009 to 2023. We observe that the proportion of ESG-rated firms remains consistently high throughout the sample period, indicating that the coverage of ESG ratings closely tracks the growth in the number of listed firms.

Figure 3 compares ESG ratings in 2009 and 2023, revealing notable shifts. In 2009, about 80% of ratings clustered between 3–4 and 4–5, with some lower ratings still present. By 2023, higher

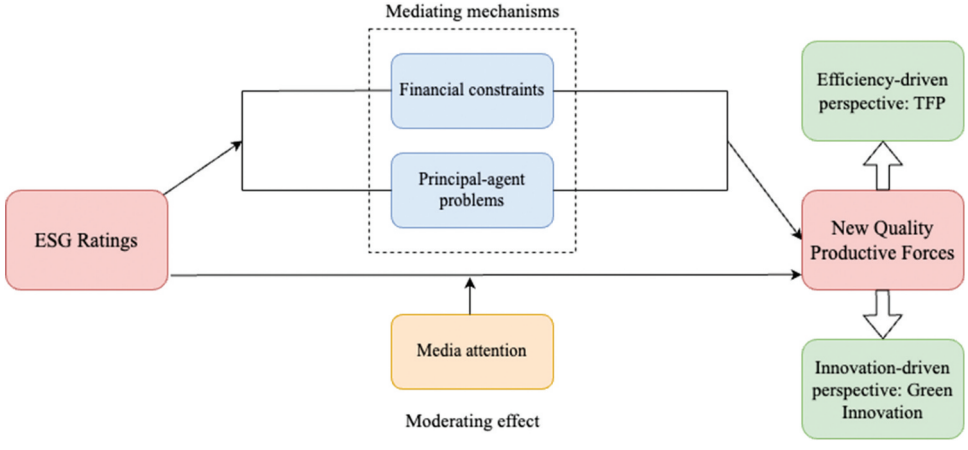

Figure 1. Conceptual framework.

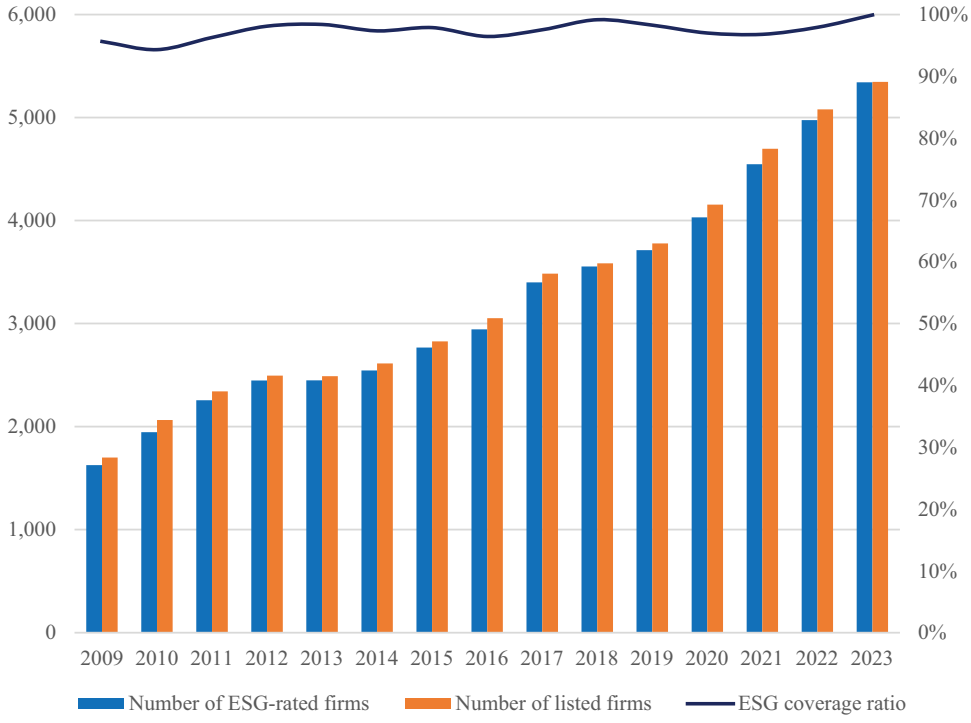

Figure 2. Coverage of ESG ratings for Chinese A-share listed firms. Source: https://www.chindices.com/esg-data.html.

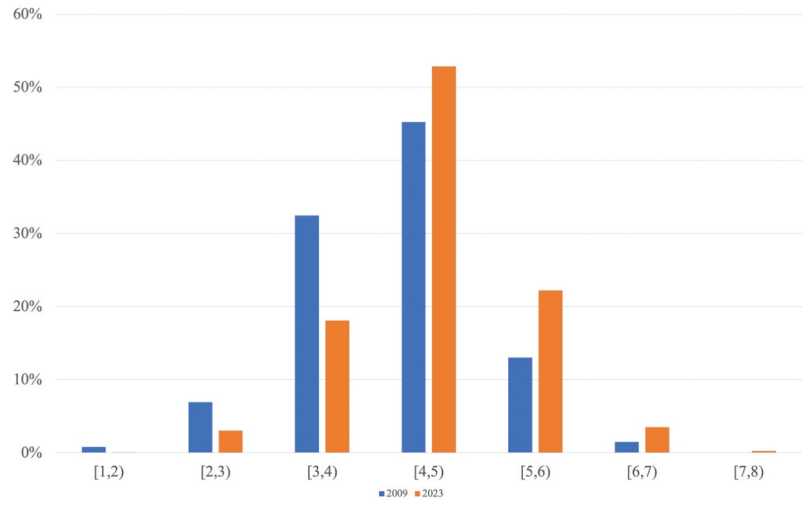

Figure 3. Distribution of ESG ratings for Chinese A-share listed firms. Source: https://www.chindices.com/esg-data.html.

ratings became predominant, with over 50% in the 4–5 range and more than 20% in 5–6. Lower ratings (1–3) have nearly disappeared. This trend indicates an overall improvement in ESG ratings in China, with reduced variability and a concentration around higher ratings.

Figure 4 depicts the average TFP of Chinese listed firms from 2009 to 2023. TFP steadily increased from 7.98 in 2009 to 8.50 in 2018, then plateaued between 2018 and 2021. A slight decline to 8.42 occurred from 2021 to 2023, likely due to COVID-19's economic impact. Despite this, the overall trend remains upward, reflecting underlying growth.

Figure 5 shows the proportion of green patent applications among total patents for Chinese listed firms from 2009 to 2023. The trend indicates a significant rise in green innovation, especially after the 2020 implementation of the 'dual carbon goals', which has incentivized firms to focus on green innovation.

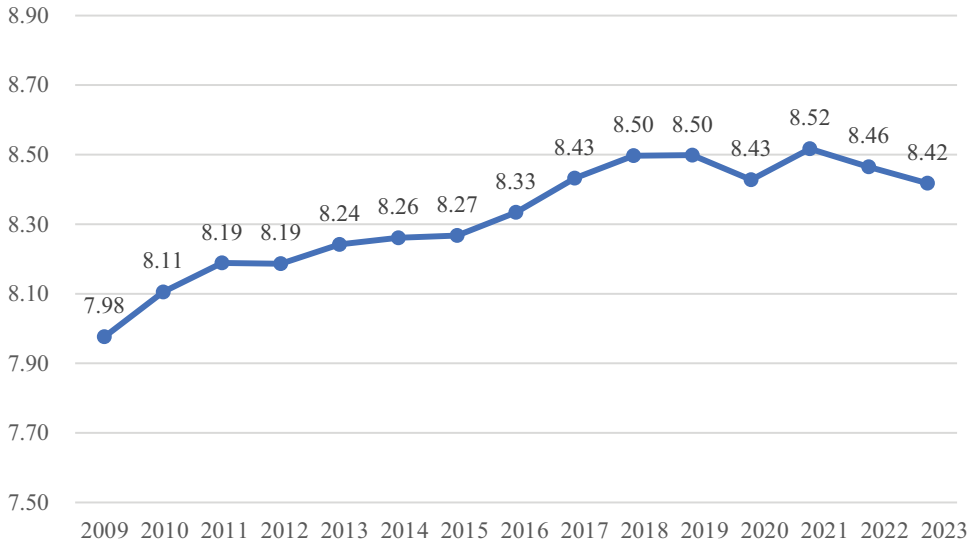

Figure 4. Trend in average TFP of Chinese A-share listed firms.

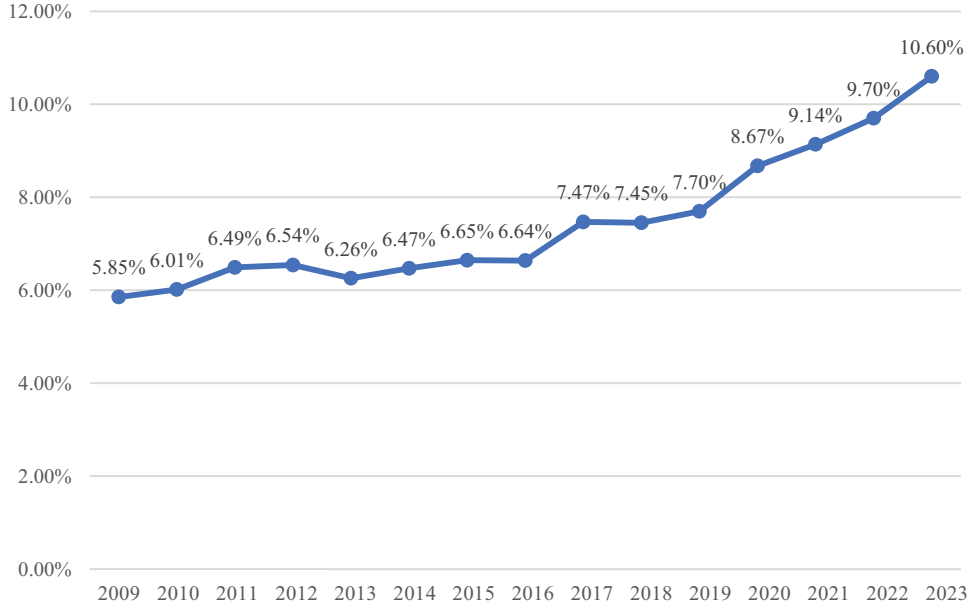

Figure 5. Proportion of green patent applications among Chinese A-share listed firms.

Figure 6 shows a positive linear relationship between ESG ratings and both TFP and green patents among Chinese listed firms. Notably, the ESG ratings-green patents plot has a slightly steeper trend line, indicating that ESG ratings have a marginally stronger impact on green innovation than on TFP.

IV. Empirical strategy

Model design and variable description

This article focuses on both efficiency-driven and innovation-driven corporate development in the Chinese context. Specifically, TFP is utilized as a proxy variable for the efficiency (Balk 2010; Dvouletý and Blažková 2021). Following the previous literature, we employ the Olley-Pakes (OP) method and Levinsohn-Petrin (LP) method to calculate TFP. The OP method addresses the simultaneity bias in production function estimation by employing the corporate investment as a proxy for the unobserved productivity (Olley and Pakes 1996). The LP method utilizes intermediate inputs as the proxy for the unobserved productivity to mitigate the endogeneity problem and minimize sample loss when estimating the production function (Levinsohn and Petrin 2003).

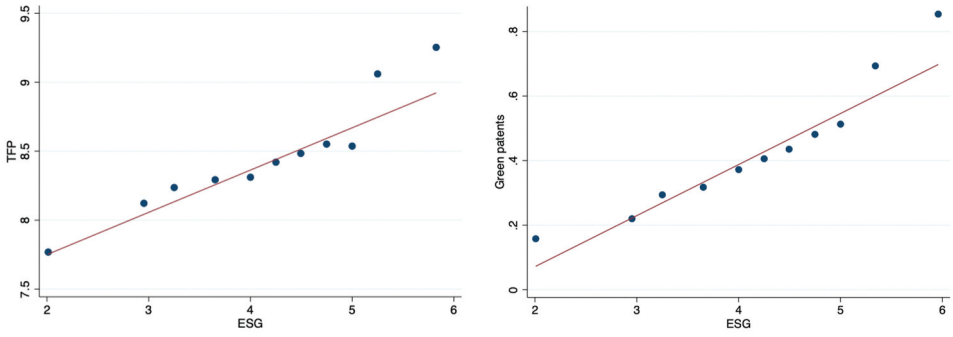

Figure 6. The correlation between ESG ratings, TFP and green patents.

Green patent (GP) applications (see Appendix A) are utilized as a proxy variable for green innovation (Kim, Pantzalis, and Zhang 2021; Xiang, Liu, and Yang 2022).

We utilize TFP and GP as two dependent variables and construct the following baseline models.

$$TFP_{it} = \beta_0 + \beta_1 ESG_{it} + \beta_2 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

$$GP_{it} = \beta_3 + \beta_4 ESG_{it} + \beta_5 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

In Equations (1) and (2), i represents the sample firm, and t denotes the year. ESG serves as the primary explanatory variable, reflecting the firm's ESG ratings. As shown in Table 1, the ESG rating is assigned on a scale from 1 to 9, corresponding to grades C, CC, CCC, B, BB, BBB, A, AA, and AAA, where higher scores indicate superior ESG performance (J. Li, Lian, and Xu 2023; H. Zhang, Lai, and Jie 2024). The ESG ratings are provided by Sino-Securities Index Information Service (Shanghai) Co. Ltd (see Appendix B).

Additionally, we include control variables that reflect firm-specific characteristics. The control variables are as follows:

Firm characteristics (Size and ListAge)

The size and listing age of a firm significantly influence its TFP and green innovation, with larger firms typically exhibiting higher levels in both areas. Firm age, as an indicator of maturity, may influence both TFP and green innovation by allowing for the accumulation of research and development (R&D) experience over time (J. Hu, Yu, and Han 2023; J. Liu and Xiao 2022; J. Xu and Cui 2020). Therefore, we include Size and ListAge as control variables to account for these effects.

Table 1. Correspondence between ESG ratings and ESG scores.

ESG Rating Level	ESG Rating Value	Adjusted ESG Score
AAA	9	score ≥ 95
AA	8	90 ≤ score < 95
A	7	85 ≤ score < 90
BBB	6	80 ≤ score < 85
BB	5	75 ≤ score < 80
B	4	70 ≤ score < 75
CCC	3	65 ≤ score < 70
CC	2	60 ≤ score < 65
C	1	score < 60

Financial performance (ROA, Lev, and Cashratio)

As key financial factors, a firm's Return on Assets (ROA), debt level, and cash holdings reflect its profitability and value creation, creditworthiness and access to external financing, and cash flow status, respectively – all of which influence TFP and green innovation (J. Liu, Liu, and Chao 2024; J. Liu and Xiao 2022; X. Yu and Chen 2024). Accordingly, ROA, Lev, and Cashratio are included as control variables in the analysis.

Firm governance structure (Top1)

The governance structure of a firm significantly influences TFP and green innovation (X. Yu and Chen 2024). Thus, we include ownership concentration (Top1) as a control variable to reflect the corporate governance structure.

External variable (Subsidy)

Existing research indicates that government subsidies, as financial incentives provided to firms, affect TFP and green innovation (Y. Wang and Li 2023). Therefore, we include government subsidies (Subsidy) as a control variable.

Besides, μ_i and λ_t denote the fixed effects of the firm and year, respectively. ε_{it} represents the

Table 2. Variable measurements.

Type	Variable	Definition
Dependent variables	TFP_OP	Total factor productivity calculated by the OP method
	TFP_LP	Total factor productivity calculated by the LP method
	GP	Natural logarithm of (1+number of green patent applications)
Independent variable	ESG	Sino-Securities ESG Rating Index
Control variables	Size	Natural logarithm of number of employees
	ListAge	Natural logarithm of (current year - year of listing + 1)
	ROA	Ratio of net income to total assets
	Lev	Ratio of total liabilities to total assets
	Cashratio	Ratio of cash holdings to total assets
	Top1	Shareholding ratio of the largest shareholder
	Subsidy	Natural logarithm of the amount of government subsidies

random disturbance term. The variable measurements are shown in Table 2.

Data and sample construction

In this article, the data used to calculate TFP are derived from China Stock Market and Accounting Research (CSMAR) database. Data on GP and ESG are obtained from the Chinese Research Data Services (CNRDS) and WIND databases, respectively. Control variables are also sourced from the CSMAR database. Our dataset is composed of non-financial firms that are publicly listed and traded on the Shanghai, Shenzhen, or Beijing Stock Exchanges. We specifically chose listed firms as our sample due to their comprehensive and reliable ESG information. To ensure the sample is unaffected by events related to the global financial crisis in 2008, we selected 2009 as the initial year for our sample period. Additionally, we excluded observations with missing data or those classified as 'special treatment' (ST) from the sample (see Appendix C). To address issues pertaining to outliers, we also winsorized certain variables at the 1st and 99th percentiles. After these steps, we obtained a panel dataset comprising 34,384 firm-year observations for the period from 2009 to 2023.

Table 3 presents detailed descriptive statistics for the main variables. The variable TFP_OP has a mean of 7.417 and a standard deviation of 0.902, indicating moderate variability across observations. The variable TFP_LP exhibits a higher mean of 8.441 and slightly greater dispersion,

Table 3. Summary statistics for main variables.

	(1)	(2)	(3)	(4)	(5)
Variables	Observations	Mean	Standard deviation	Minimum	Maximum
TFP_OP	34,384	7.417	0.902	5.686	10.090
TFP_LP	34,384	8.441	1.042	6.194	11.449
GP	34,384	0.468	0.900	0	7.062
ESG	34,384	4.210	0.779	1	7.750
Size	34,384	7.669	1.211	5.088	11.193
ListAge	34,384	1.900	0.917	0	3.526
ROA	34,384	0.043	0.056	−0.191	0.211
Lev	34,384	0.391	0.193	0.048	0.832
Cashratio	34,384	0.176	0.134	0.013	0.653
Top1	34,384	0.341	0.148	0.085	0.751
Subsidy	34,384	16.324	1.460	12.249	20.136

with a standard deviation of 1.042. Moreover, the variable GP has a mean of 0.468, indicating that the green innovation level of the sample firms is relatively low. Its values range from 0 to 7.062, with a standard deviation of 0.911, indicating considerable variation in green innovation among sample firms. Finally, the variable ESG has a mean of 4.210 and a standard deviation of 0.779, suggesting notable variation in firms' ESG ratings.

V. Baseline results

Baseline regressions

Table 4 reports the results of the baseline regressions. Columns (1) and (2) show the impact of ESG ratings on TFP, while column (3) presents the effect of ESG ratings on green innovation. The regression coefficients are all significantly positive at the 1% level, indicating that ESG ratings significantly enhance corporate TFP and green innovation, thereby promoting efficiency-driven and innovation-driven development at the firm level. Notably, a comparison of the results reveals that ESG ratings have a more pronounced positive influence on green innovation.

In the examination of control variables, the coefficients of the ROA and Subsidy variables are significantly positive in both regressions of TFP and green innovation, indicating that firms with higher asset efficiency and stronger government support tend to exhibit higher levels of TFP and green innovation.

Robustness tests

Replacement of dependent variables

Columns (1) and (2) of Table 5 shows the regression results after replacing the dependent variable

Table 4. Baseline regression results.

VARIABLES	(1) TFP_OP	(2) TFP_LP	(3) GP
ESG	0.022***	0.019***	0.030***
	(0.005)	(0.005)	(0.008)
Size	0.028	0.344***	0.059***
	(0.019)	(0.017)	(0.013)
ListAge	0.075***	0.014	0.007
	(0.012)	(0.012)	(0.015)
ROA	2.996***	3.011***	0.158*
	(0.089)	(0.091)	(0.084)
Lev	0.988***	0.918***	0.004
	(0.053)	(0.054)	(0.049)
Cashratio	0.162***	0.291***	−0.022
	(0.041)	(0.043)	(0.048)
Top1	−0.262**	−0.292***	−0.073
	(0.105)	(0.099)	(0.085)
Subsidy	0.057***	0.040***	0.017***
	(0.005)	(0.005)	(0.005)
Constant	5.577***	4.597***	−0.387***
	(0.141)	(0.132)	(0.132)
Observations	34,384	34,384	34,384
R-squared	0.901	0.922	0.716
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

TFP, as a part of robustness tests. The TFP for firms is recalculated using the ACF correction method (TFP_ACF) and generalized method of moments (TFP_GMM). The ACF correction method addresses identification issues in estimating variable input coefficients by employing the inverse of a 'conditional' input demand function and accommodating labour adjustment costs and dynamic effects (Ackerberg, Caves, and Frazer 2015). GMM method jointly estimates all parameters, addressing endogeneity through instrumental variables, and provides robust standard error estimates under serial correlation and heteroskedasticity, thereby enhancing estimation efficiency (Wooldridge 2009). The results remain consistent with the baseline regressions, showing a significantly positive impact of the ESG ratings on TFP at the 1% level.

Moreover, since green patent applications mainly reflect the quantity of green innovation, we further utilize the number of green patent grants (GP_grants) and green patent citations (GP_citations) to assess the quality of green innovation (Dong et al. 2025; Dou et al. 2025). This enables us to examine whether ESG ratings substantively contribute to enhancing the quality of corporate green innovation. As shown in Columns (3) and (4) of Table 5, the results remain

Table 5. Robustness test: replacement of dependent variables.

VARIABLES	(1) TFP_ACF	(2) TFP_GMM	(3) GP_grants	(4) GP_citations
ESG	0.022***	0.017***	0.027***	0.027***
	(0.005)	(0.005)	(0.007)	(0.008)
Controls	Yes	Yes	Yes	Yes
Observations	34,384	34,384	34,384	34,384
R-squared	0.863	0.840	0.715	0.805
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

statistically significant at the 1% level, reinforcing the robustness of the baseline findings.

Replacement of explanatory variables

We conduct robustness tests by replacing the key explanatory variable ESG. It is replaced with ESG scores measured on a 100-point scale.Table 6 presents the regression results, which reaffirm the significantly positive impact of ESG ratings on both corporate TFP and green innovation.

To gain further insights, we utilize the Sino-Securities sub-ratings to examine the specific effects of the environmental and social pillars of ESG ratings on TFP and green innovation, while including the governance pillar as a control variable. As illustrated in Table 7, both the environmental component (E_score) and the social component (S_score) have a significantly positive effect on TFP and green innovation.

Furthermore, we utilize the WIND ESG Ratings (see Appendix D) as an alternative data source for assessing corporate ESG performance. Table 8 presents the regression results using WIND ESG Ratings (WIND_ESG) as the core explanatory variable, further confirming the significantly positive impact of ESG ratings on corporate TFP and green innovation.

Consideration of external shocks

To address potential concerns about external shocks, we conducted robustness checks by excluding the impact of the COVID-19 pandemic. Specifically, we re-estimated our baseline regressions after excluding observations from the pandemic-affected years from 2020 to 2022. As shown in Table 9, the results remain robust. The effects of ESG ratings on both TFP and green innovation remain positively significant.

Table 6. Robustness test: replacement of explanatory variables.

VARIABLES	(1) TFP_OP	(2) TFP_LP	(3) GP
ESG_score	0.003***	0.002***	0.006***
	(0.001)	(0.001)	(0.001)
Controls	Yes	Yes	Yes
Observations	34,172	34,172	34,172
R-squared	0.901	0.922	0.717
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Table 7. Robustness test: ESG component variables.

VARIABLES	(1) TFP_OP	(2) TFP_LP	(3) GP	(4) TFP_OP	(5) TFP_LP	(6) GP
E_score	0.002***	0.001**	0.002**			
	(0.001)	(0.001)	(0.001)			
S_score				0.002***	0.001***	0.002***
				(0.000)	(0.000)	(0.001)
G_score	0.001*	0.001	0.002***	0.001*	0.001	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	34,172	34,172	34,172	34,172	34,172	34,172
R-squared	0.901	0.922	0.717	0.901	0.922	0.717
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Consideration of lagged effects

Given that green innovation involves longer development cycles – such as R&D investments and the integration of sustainable practices – which inherently take time to mature and fully realize their benefits, we apply both one-period (LagESG) and two-period (Lag2ESG) lagged treatments to the ESG variable to re-examine its effect on corporate green innovation. As shown in Table 10, after incorporating these lagged effects, the regression coefficients of ESG ratings remain positively significant. This suggests that the impact of ESG ratings on green innovation tends to be more prolonged, with effects materializing over multiple subsequent periods as these ongoing efforts bears fruit. These findings are consistent with existing literature (Feng, Ma, and Wu 2025; Wu et al. 2024; H. Zhang, Lai, and Jie 2024).

Consideration of green patent classifications

The GP variable includes applications for both green utility model patents and green invention patents. Columns (1) and (2) of Table 11 present the results when the GP variable is replaced by applications for green utility model patents (Green utility) and green invention patents (Green invention), respectively (see Appendix E). The results indicate that the effects of ESG ratings on applications for both green utility models and green inventions are significantly positive at the 1% level, with a stronger effect on green invention patents.

Table 8. Robustness test: alternative data.

VARIABLES	(1) TFP_OP	(2) TFP_LP	(3) GP
WIND_ESG	0.039***	0.031***	0.032***
	(0.006)	(0.006)	(0.008)
Controls	Yes	Yes	Yes
Observations	23,249	23,249	23,649
R-squared	0.928	0.941	0.800
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Table 9. Robustness test results: consideration of external shocks.

VARIABLES	(1) TFP_OP	(2) TFP_LP	(3) GP
ESG	0.020***	0.014***	0.030***
	(0.005)	(0.005)	(0.008)
Controls	Yes	Yes	Yes
Observations	22,306	22,306	22,306
R-squared	0.901	0.921	0.712
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Endogenous processing

To address the potential endogeneity concerns, we employ the instrumental variable (IV) approach to enhance robustness. We use the value of a firm's ESG fund holdings as an instrumental variable (denoted as VESGF). On one hand, as institutional investors that prioritize ESG practices, ESG funds not only hold shares but also engage actively in corporate governance, thereby influencing firm's ESG performance and establishing a positive correlation with their ESG ratings (Dyck et al. 2019), which satisfies the relevance criterion. On the other hand, the establishment and scale of ESG funds are determined externally by fund management companies (Xie and Lyu 2022) and are unlikely to directly affect firm-level TFP or green innovation, which are primarily driven by internal scientific

Table 10. Robustness test: lagged effects.

VARIABLES	(1) GP	(2) GP
LagESG	0.016**	
	(0.008)	
Lag2ESG		0.015*
		(0.008)
Controls	Yes	Yes
Observations	29,428	25,289
R-squared	0.732	0.738
Firm FE	Yes	Yes
Year FE	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Table 11. Robustness test: consideration of green patent classifications.

VARIABLES	(1) Green utility	(2) Green invention
ESG	0.020***	0.024***
	(0.006)	(0.007)
Controls	Yes	Yes
Observations	34,384	34,384
R-squared	0.661	0.700
Firm FE	Yes	Yes
Year FE	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

knowledge and engineering expertise (Fang and Hu 2023). Therefore, the ESG fund holdings fulfill the exogeneity requirement for our analysis.

Table 12 shows the results of the instrumental variable tests. The Kleibergen-Paap rk LM statistics reject the under-identification hypothesis, while the Cragg-Donald Wald F statistics and Kleibergen-Paap rk Wald F statistics reject the weak identification hypothesis. These findings indicate the validity and reliability of the instrumental variable. Even when considering the endogeneity issue, the coefficients of ESG variable remain significantly positive.

VI. Mechanism analyses

Mediating mechanisms

In this section, drawing upon Wen and Ye (2014), we further explore the mechanisms through which ESG ratings affect corporate TFP and green innovation by constructing the mediation effect model (see Appendix F).

Table 12. Endogenous test results: instrumental variable.

VARIABLES	(1) ESG	(2) TFP_OP	(3) TFP_LP	(4) GP
ESG		0.321***	0.247***	0.312***
		(0.060)	(0.047)	(0.082)
VESGF	0.273***			
	(0.002)			
Controls	Yes	Yes	Yes	Yes
Observations	34,384	34,384	34,384	34,384
R-squared		0.212	0.333	0.008
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Kleibergen-Paap rk LM statistic		14.29	14.29	14.29
Cragg-Donald Wald F statistic		64496	64496	64496
Kleibergen-Paap rk Wald F statistic		31511	31511	31511

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Financing constraints

Financing constraints are a critical factor affecting corporate performance. To boost production efficiency and innovation capabilities, firms need substantial capital investments and access to external financing. However, information asymmetry significantly hinders the acquisition of such financing. This section explores whether financing constraints serve as a mechanism through which ESG ratings affect TFP and green innovation.

Building on the research conducted by Hadlock and Pierce (2010), we utilize the SA index to measure financing constraints, with the SA index calculated using Equation (3). The variable *Size* is consistent with the previous definition, while *Age* represents the years of establishment of the firm.

$$SA = -0.737 \times Size + 0.043 \times Size^2 - 0.040 \times Age \quad (3)$$

Table 13 reports the regression results for the financing constraint mechanism tests. Column (1) shows the regression of the absolute value of the SA index on ESG, suggesting that ESG ratings help alleviate financing constraints faced by firms. Furthermore, the estimation results in Columns (2) to (4) provide evidence of a partial mediation effect related to firms' financing constraints. These findings confirm that ESG ratings can ease firms' financing constraints and thus promoting their TFP and green innovation.

Table 13. Mediating mechanism results: easing financial constraints.

VARIABLES	(1) SA	(2) TFP_OP	(3) TFP_LP	(4) GP
SA		−0.870***	−0.608***	−0.726***
		(0.158)	(0.153)	(0.152)
ESG	−0.004***	0.019***	0.017***	0.027***
	(0.001)	(0.005)	(0.005)	(0.008)
Controls	Yes	Yes	Yes	Yes
Observations	34,376	34,376	34,376	34,376
R-squared	0.984	0.902	0.922	0.717
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Table 14. Mediating mechanism results: mitigating principal-agent problems.

VARIABLES	(1) Agencycost	(2) TFP_OP	(3) TFP_LP	(4) GP
Agencycost		−4.513***	−4.539***	−0.261*
		(0.149)	(0.145)	(0.141)
ESG	−0.003***	0.007	0.004	0.029***
	(0.001)	(0.005)	(0.005)	(0.008)
Controls	Yes	Yes	Yes	Yes
Observations	34,384	34,384	34,384	34,384
R-squared	0.761	0.923	0.939	0.716
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Principal-agent problems

The separation of ownership and control within firms leads to principal-agent problems, resulting in divergent interests and goals between owners and managers. This often gives rise to agency conflicts and associated agency costs (Jensen and Meckling 1976), which negatively affect corporate management and strategic decision-making. Specifically, firm managers may prioritize short-term performance and their personal interests, often overlooking high-risk investments that could enhance the firm's long-term value (He and Tian 2013).

In this section, we investigate whether ESG ratings can mitigate principal-agent problems and thereby promote TFP and green innovation within firms. Building on the research by X. Yu and Chen (2024), we utilize the ratio of management expenses to operating income as an indicator of the extent of agency costs (Agencycost), reflecting potential conflicts of interest between shareholders and executives.

Table 14 shows the regression results for the principal-agent mechanism tests. Higher ESG ratings are associated with lower agency costs, while lower agency costs are positively linked to higher TFP and green innovation. This pattern supports the idea that reducing agency costs through better ESG performance can promote corporate TFP and green innovation.

Moderating effect

Media attention

Media serves as a pivotal channel between the public and firms, playing a crucial role in attracting public attention, influencing public opinion, and establishing corporate social image (Miller 2006). Through news reporting, the media disseminates information and influences the public's attention and focus on firm-specific issues, such as sustainability and green innovation (Burke 2022). This agenda-setting role of the media triggers stakeholder perceptions and reactions that affect corporate sustainable performance (Pollach 2014). Additionally, the media reduces the information acquisition costs for stakeholders, enhances transparency, and fosters increased public oversight (Dyck and Zingales 2004). For the public, media coverage provides an alternative source for obtaining information about firms, supplementing the proactive disclosures made by those firms (Y. Liu et al. 2023).

Both media coverage and ESG ratings function as informal institutional mechanisms that enhance transparency and strengthen public oversight. This raises an important question: do ESG ratings and media attention function as complements or substitutes in promoting TFP and green innovation? Therefore, in this section, we examine whether media attention moderates the impact of ESG ratings on corporate TFP and green innovation.

Following the methodology of Y. Liu et al. (2023), we construct the Media variable by employing the number of news reports on firms – specifically, the total number of mentions of a firm in online news headlines and financial articles from newspapers – as a proxy for media attention. This data is sourced from the CNRDS database. Equations (4) and (5) incorporate the interaction term $Media_{it} \times ESG_{it}$ to investigate the moderating

impact of media attention in the positive correlation between the ESG variable and the two dependent variables TFP and GP.

$$TFP_{it} = \alpha_0 + \alpha_1 Media_{it} \times ESG_{it} + \alpha_2 ESG_{it} + \alpha_3 Media_{it} + \alpha_4 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

$$GP_{it} = \alpha_5 + \alpha_6 Media_{it} \times ESG_{it} + \alpha_7 ESG_{it} + \alpha_8 Media_{it} + \alpha_9 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (5)$$

Table 15 presents the regression results for Equations (4) and (5), which evaluate the moderating effect of media attention. Due to the considerable differences in scales between the variables of Media and ESG, we standardized the individual variables of ESG and Media to ensure comparability. The results indicate that the coefficients of the interaction term $Media_{it} \times ESG_{it}$ are all significantly positive for both TFP and GP. Specifically, the coefficients of the interaction term $Media_{it} \times ESG_{it}$ can be interpreted as the expected change in TFP and GP associated with a one standard deviation increase in both variables of Media and ESG.

VII. Further analyses

Greenwashing issue

Greenwashing is a deceptive practice in which organizations misrepresent their environmental practices or the ecological benefits through exaggerated claims about environmental benefits and by overstating overall environmental performance. Such practices can mislead consumers and investors, diverting attention and resources away from genuinely sustainable initiatives.

Building on existing literature (X. Hu et al. 2023), we quantitatively measure greenwashing (see Appendix G). Table 16 presents the regression results of the Greenwashing variable on ESG ratings. The coefficient for ESG variable is significantly negative at the 1% level, indicating that higher ESG ratings tend to mitigate corporate greenwashing. Firms with high ESG ratings exhibit stronger alignment between their environmental claims and actual practices. These firms are typically subject to stricter external monitoring, transparency requirements, and reputational risks, which reduce their inclination to make false or exaggerated environmental claims. Moreover, their incentive to protect reputational capital encourages consistency between stated commitments and actual environmental performance.

Heterogeneity analyses

Policy environment

The impact of ESG ratings on high-quality and sustainable development may vary depending on the regional policy environment. The establishment of pilot free trade zones (PFTZ)[3] represents a major strategic initiative in China's pursuit of reform and opening-up in the new era. PFTZs have facilitated the accelerated development of emerging industries, new business forms, and innovative models, progressively becoming demonstrators and leaders of high-quality

Table 15. Moderating effect results: media attention.

VARIABLES	(1) TFP_OP	(2) TFP_LP	(3) GP
Media × ESG	0.009***	0.008***	0.009*
	(0.003)	(0.003)	(0.005)
ESG	0.015***	0.013***	0.022***
	(0.004)	(0.004)	(0.006)
Media	0.034***	0.029***	0.023***
	(0.005)	(0.005)	(0.008)
Controls	Yes	Yes	Yes
Observations	33,104	33,104	33,104
R-squared	0.902	0.923	0.718
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Table 16. Greenwashing.

VARIABLES	(1) Greenwashing	(2) Greenwashing
ESG	0.011**	−0.014***
	(0.004)	(0.004)
Controls	No	Yes
Observations	34,126	34,126
R-squared	0.001	0.459
Firm FE	No	Yes
Year FE	No	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

[3]The State Council, People's Republic of China. Expanding Development Space for Chinese Modernization: High-Level Opening-Up Through Pilot Free Trade Zones and Free Trade Ports. (in Chinese). https://www.gov.cn/yaowen/liebiao/202409/content_6975044.htm.

development in China and advancing 'New Quality Productive Forces'. To examine this, we divide firms into two subsamples based on their geographical location: those in provinces with Pilot Free Trade Zones (the PFTZ-located group; see Appendix H) and those outside these zones (non-PFTZ-located group).

As shown in Table 17, the results indicate a significant difference in the impact of ESG ratings on TFP and green innovation between the two groups. Specifically, ESG ratings have a notable positive effect within the PFTZ-located group.

First, PFTZs have introduced a series of plans and regulations focused on ecological and environmental protection, making considerable efforts to implement these measures effectively (C. Zhang et al. 2024). Moreover, PFTZs facilitate firms in aligning with international operational and ESG standards. By expanding market access, PFTZs attract substantial foreign investment and introduce global investment concepts, assisting local firms in better adhering to international ESG standards and further incentivizing their sustainability improvements (Zeng, Zhang, and Li 2024). Serving as a pivotal initiative for institutional opening-up, PFTZs have delivered substantial benefits, creating an environment conducive to enhancing ESG ratings among local firms.

Second, PFTZs support firms in enhancing production efficiency and fostering green innovation. On one hand, the establishment of PFTZs fosters an open and dynamic economic environment that facilitates the frequent mobility of human capital, facilitating knowledge spillovers that improve firms' production efficiency. Additionally, PFTZs promote the liberalization of China's capital market and facilitating the efficient circulation of international capital, granting firms access to abundant external financial resources. This supports their investment in productivity-enhancing activities and improves their TFP (J. Chen, Yang, and Wu 2024). On the other hand, policy incentives in PFTZs – such as tax reductions – reduce operational costs and support long-term R&D in green technologies. Improved access to green finance alleviates financial constraints and incentivizes firms to engage in green innovation and adopt innovation-driven strategies (Lei and Xie 2024). Firms operating within these zones benefit from a more flexible regulatory environment and increased financial support, which facilitate their growth and innovation. Specifically, our findings indicate that PFTZs have a significant promoting effect on the application of firms' green utility patents.

Table 17. Heterogeneity analysis: policy environment.

VARIABLES	(1) TFP_OP	(2) TFP_OP	(3) TFP_LP	(4) TFP_LP	(5) GP: Green Utility	(6) GP: Green Utility
	PFTZ	non-PFTZ	PFTZ	non-PFTZ	PFTZ	non-PFTZ
ESG	0.023***	0.004	0.020***	0.000	0.021***	0.002
	(0.005)	(0.018)	(0.005)	(0.016)	(0.006)	(0.013)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	32,370	2,013	32,370	2,013	32,370	2,013
R-squared	0.901	0.915	0.922	0.936	0.662	0.625
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Industry factor intensity

The characteristics of an industry can lead to variations in how ESG ratings influence TFP and green innovation. Based on the research of Lu and Dang (2014), industries are divided into three categories according to their factor intensity: labour-intensive, capital-intensive, and technology-intensive (see Appendix I), in line with the industry classification by the China Securities Regulatory Commission (CSRC).

As indicated in Table 18, ESG ratings have a more significantly positive effect on TFP and green innovation among firms in technology-intensive and capital-intensive industries. Technology-intensive industries thrive on innovation and prioritize R&D expenditures (Yin, Sheng, and Li 2018). These sectors require significant technological resources during production processes to maintain competitiveness. On the other hand, capital-intensive industries necessitate substantial capital investments in production and rely heavily on advanced equipment and technology (F. Wang and Li 2005). Companies in these industries typically face sizable initial investment requirements and prolonged payback periods.

ESG ratings play a crucial role in both sectors by alleviating financing constraints and emphasizing

Table 18. Heterogeneity analysis results: industry factor intensity.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	TFP_OP			TFP_LP			GP		
	Technology-intensive	Capital-intensive	Labour-intensive	Technology-intensive	Capital-intensive	Labour-intensive	Technology-intensive	Capital-intensive	Labour-intensive
ESG	0.057***	0.030***	0.013*	0.044**	0.029***	0.010	0.035*	0.037***	0.014
	(0.022)	(0.006)	(0.008)	(0.022)	(0.007)	(0.007)	(0.018)	(0.014)	(0.011)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,232	14,483	13,820	2,232	14,483	13,820	2,232	14,483	13,820
R-squared	0.950	0.932	0.909	0.960	0.947	0.933	0.782	0.752	0.664
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

Table 19. Heterogeneity analysis: ownership structure.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	TFP_OP		TFP_LP		GP	
	State-owned	Non-State-owned	State-owned	Non-State-owned	State-owned	Non-State-owned
ESG	0.021**	0.029***	0.017*	0.026***	0.017	0.032***
	(0.010)	(0.006)	(0.009)	(0.006)	(0.015)	(0.009)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,991	23,949	9,991	23,949	9,991	23,949
R-squared	0.911	0.902	0.936	0.920	0.767	0.714
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

The data in parentheses are robust standard errors for firm-level clustering. ***, ** and * denote passing significance tests at the levels of 1%, 5%, and 10%, respectively.

long-term corporate development. Consequently, the positive effects of ESG ratings substantially enhance TFP and foster green innovation within both capital-intensive and technology-intensive firms.

Ownership structure

The impact of ESG ratings on TFP and green innovation may vary depending on ownership structure, warranting an investigation into its heterogeneity. As shown in Table 19, the positive impact of ESG ratings on TFP is significant for both state-owned enterprises (SOEs) and non-state-owned enterprises (non-SOEs). For both types, better ESG ratings is associated with greater improvements in TFP. However, the impact of ESG ratings on green innovation is only statistically significant within the non-SOEs group.

SOEs often bear broader policy responsibilities that shape their ESG performance to be primarily compliance-oriented rather than innovation-driven. Their environmental actions are typically guided by top-down mandates rather than market competition, limiting their proactive engagement in green technological advancement. In contrast, operating in a competitive market environment, non-SOEs are more motivated to strengthen their competitiveness through investments in R&D activities and improvements in ESG performance (F. Wang 2024). This motivation helps them maintain competitiveness by continuously adopting and applying new green technologies, driving green transformation, and elevating their level of green innovation.

Furthermore, the managerial incentives within SOEs are tightly constrained by their political responsibilities and operate under specific regulatory frameworks, often prioritizing predefined objectives. SOE managers, typically appointed by the government, face strong political pressures in green transition efforts, frequently without corresponding financial incentives. This reduces their motivation and makes them more risk-averse regarding innovation (R. Liu et al. 2024). Therefore, SOEs tend to be less responsive to improvements in ESG performance, and such improvements are often insufficient to prompt meaningful adjustments in internal decision-

making processes (Hussain et al. 2024). Their bureaucratic structures and slow decision-making further limit their capacity to prioritize green innovation, thus hindering their ability to contribute significantly to low-carbon green transformation efforts. In contrast, non-SOEs demonstrate greater flexibility in capital decision-making and operational management, enabling them to align their ESG ratings more effectively with sustainability goals. This flexibility results in a more significant impact on green innovation. Additionally, non-SOEs allocate a larger proportion of their revenues to R&D investments, enabling them to focus more effectively on green innovation initiatives.

VIII. Conclusions

This article conceptualizes 'New Quality Productive Forces' within the Chinese context by integrating TFP and green innovation into a unified framework, enabling a comparative analysis of ESG ratings from efficiency-driven and innovation-driven perspectives. Findings show that ESG ratings significantly enhance both TFP and green innovation, with a stronger effect on green innovation. Robustness tests using alternative indicators confirm that ESG ratings positively influence TFP and both the quantity and quality of green innovation.

The positive effects operate through several mechanisms. Specifically, ESG ratings promote TFP and green innovation by alleviating financing constraints and mitigating principal-agent issues. Additionally, media attention positively moderates the beneficial impact of ESG ratings on TFP and green innovation.

Further analysis reveals that higher ESG ratings substantially limit greenwashing behaviour. Heterogeneity analyses indicate that ESG ratings' effectiveness varies by regional policy, industry sector, ownership structure, and firm characteristics, with more pronounced effects in PFTZs and in technology- and capital-intensive sectors.

This study contributes both empirically and policy-wise by demonstrating that high ESG ratings support firms in achieving 'New Quality Productive Forces'. Firms that embrace corporate social responsibility can enhance their corporate image, attract stakeholder support, and promote sustainable development.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the WTO Chairs Program under Grant number: [H2202401]; National Social Science Foundation of China under Grant number: [20CGJ016]; Project of the Key Research Base of Humanities and Social Sciences of the Ministry of Education of China under Grant number: [22JJD810003]; Sino-Swiss Competence Center (SSCC) of University of International Business and Economics under Grant number: [78170411].

ORCID

Siqi Li http://orcid.org/0000-0002-3996-462X
Yangkai Jin http://orcid.org/0009-0006-2812-9617

References

Ackerberg, D. A., K. Caves, and G. Frazer. 2015. "Identification Properties of Recent Production Function Estimators." *Econometrica* 83 (6): 2411–2451. https://doi.org/10.3982/ECTA13408.

Asimakopoulos, P., S. Asimakopoulos, and X. Li. 2023. "The Role of Environmental, Social, and Governance Rating on Corporate Debt Structure." *Journal of Corporate Finance* 83:102488. https://doi.org/10.1016/j.jcorpfin.2023.102488.

Balk, B. M. 2010. "An Assumption-Free Framework for Measuring Productivity Change." *Review of Income and Wealth* 56 (s1): S224–S256. https://doi.org/10.1111/j.1475-4991.2010.00388.x.

Benlemlih, M., and M. Bitar. 2018. "Corporate Social Responsibility and Investment Efficiency." *Journal of Business Ethics* 148 (3): 647–671. https://doi.org/10.1007/s10551-016-3020-2.

Biggerstaff, L., D. C. Cicero, and A. Puckett. 2017. "FORE! An Analysis of CEO Shirking." *Management Science* 63 (7): 2302–2322. https://doi.org/10.1287/mnsc.2016.2452.

Bofinger, Y., K. J. Heyden, and B. Rock. 2022. "Corporate Social Responsibility and Market Efficiency: Evidence from ESG and Misvaluation Measures." *Journal of Banking and Finance* 134:106322. https://doi.org/10.1016/j.jbankfin.2021.106322.

Brammer, S., C. Brooks, and S. Pavelin. 2006. "Corporate Social Performance and Stock Returns: UK Evidence from Disaggregate Measures." *Financial Management* 35 (3):

97–116. https://doi.org/10.1111/j.1755-053X.2006.tb00149.x.

Burke, J. J. 2022. "Do Boards Take Environmental, Social, and Governance Issues Seriously? Evidence from Media Coverage and CEO Dismissals." *Journal of Business Ethics* 176 (4): 647–671. https://doi.org/10.1007/s10551-020-04715-x.

Caggese, A. 2019. "Financing Constraints, Radical Versus Incremental Innovation, and Aggregate Productivity." *American Economic Journal Macroeconomics* 11 (2): 275–309. https://doi.org/10.1257/mac.20160298.

Chen, J., B. Yang, and M. Wu. 2024. "The Impact of Free-Trade Zones on Total Factor Productivity: Evidence from China." *Journal of the Knowledge Economy* 15 (4): 17649–17675. https://doi.org/10.1007/s13132-024-01850-y .

Cohen, L., U. G. Gurun, and Q. H. Nguyen. 2020. "The ESG-Innovation Disconnect: Evidence from Green Patenting." No. W27990, National Bureau of Economic Research. https://www.nber.org/papers/w27990 .

Cui, M., and D. Li. 2024. "The ESG Premium in China's A-Share Market: A Time Horizon Perspective." *Applied Economics* 56 (56): 7437–7453. https://doi.org/10.1080/00036846.2023.2283777.

De Meyst, K. J., E. Cardinaels, and A. Van den Abbeele. 2024. "CSR Disclosures in Buyer-Seller Markets: The Impact of Assurance of CSR Disclosures and Incentives for CSR Investments." *Accounting, Organizations & Society* 113:101498. https://doi.org/10.1016/j.aos.2023.101498.

Dimson, E., O. Karakaş, and X. Li. 2015. "Active Ownership." *Review of Financial Studies* 28 (12): 3225–3268. https://doi.org/10.1093/rfs/hhv044.

Dong, X., N. Zhou, X. Zhao, and S. Yang. 2025. "The Impact of Artificial Intelligence on Corporate Green Innovation: Can "Increasing Quantity" and "Improving Quality" Go Hand in Hand." *Journal of Environmental Management* 376:124439. https://doi.org/10.1016/j.jenvman.2025.124439.

Dou, W., H. Zhang, B. Miao, and B. Wang. 2025. "How Do Analyst Attention and Green Credit Promote Corporate Green Innovation?" *International Review of Economics & Finance* 99:104037. https://doi.org/10.1016/j.iref.2025.104037.

Dvouletý, O., and I. Blažková. 2021. "Exploring Firm-Level and Sectoral Variation in Total Factor Productivity (TFP)." *International Journal of Entrepreneurial Behavior and Research* 27 (6): 1526–1547. https://doi.org/10.1108/IJEBR-11-2020-0744.

Dyck, A., K. V. Lins, L. Roth, and H. F. Wagner. 2019. "Do Institutional Investors Drive Corporate Social Responsibility? International Evidence." *Journal of Financial Economics* 131 (3): 693–714. https://doi.org/10.1016/j.jfineco.2018.08.013.

Dyck, A., and L. Zingales. 2004. "Private Benefits of Control: An International Comparison." *Journal of Finance* 59 (2): 537–600. https://doi.org/10.1111/j.1540-6261.2004.00642.x.

Eliwa, Y., A. Aboud, and A. Saleh. 2019. "ESG Practices and the Cost of Debt: Evidence from EU Countries." *Critical Perspectives on Accounting* 79:102097. https://doi.org/10.1016/j.cpa.2019.102097.

Fang, X., and D. Hu. 2023. "Corporate ESG Performance and Innovation: Empirical Evidence from A-Share Listed Companies." *Economic Research Journal* 58 (2): 91–106. (in Chinese).

Feng, R., L. Ma, and D. Wu. 2025. "ESG Performance and Corporate Innovation Under the Moderating Effect of Firm Size." *International Review of Economics & Finance* 97:103774. https://doi.org/10.1016/j.iref.2024.103774.

Flammer, C. 2015. "Does Corporate Social Responsibility Lead to Superior Financial Performance? A Regression Discontinuity Approach." *Management Science* 61 (11): 2549–2568. https://doi.org/10.1287/mnsc.2014.2038.

Gehricke, S. A., X. Ruan, and J. E. Zhang. 2024. "Doing Well While Doing Good: ESG Ratings and Corporate Bond Returns." *Applied Economics* 56 (16): 1916–1934. https://doi.org/10.1080/00036846.2023.2178624.

Ghitti, M., G. Gianfrate, and L. Palma. 2024. "The Agency of Greenwashing." *Journal of Management & Governance* 28 (3): 905–941. https://doi.org/10.1007/s10997-023-09683-8.

Ghoul, S. E., O. Guedhami, and Y. Kim. 2017. "Country-Level Institutions, Firm Value, and the Role of Corporate Social Responsibility Initiatives." *Journal of International Business Studies* 48 (3): 360–385. https://doi.org/10.1057/jibs.2016.4.

Guo, X., S. Li, X. Song, and Z. Tang. 2024. "ESG, Financial Constraint and Financing Activities: A Study in the Chinese Market." *Accounting & Finance* 64 (2): 1637–1663. https://doi.org/10.1111/acfi.13196.

Hadlock, C. J., and J. R. Pierce. 2010. "New Evidence on Measuring Financial Constraints: Moving Beyond the KZ Index." *Review of Financial Studies* 23 (5): 1909–1940. https://doi.org/10.1093/rfs/hhq009.

Han, W., R. Zhang, and F. Zhao. 2024. "The Measurement of New Quality Productivity and New Driving Force of the Chinese Economy." *Journal of Quantitative & Technological Economics* 41 (6): 5–25. (in Chinese).

He, J., and X. Tian. 2013. "The Dark Side of Analyst Coverage: The Case of Innovation." *Journal of Financial Economics* 109 (3): 856–878. https://doi.org/10.1016/j.jfineco.2013.04.001.

Hu, J., X. Yu, and Y. Han. 2023. "Can ESG Rating Promote Green Transformation of Enterprises?" *Journal of Quantitative & Technological Economics* 40 (7): 90–111. (in Chinese).

Hu, X., R. Hua, Q. Liu, and C. Wang. 2023. "The Green Fog: Environmental Rating Disagreement and Corporate Greenwashing." *Pacific-Basin Finance Journal* 78:101952. https://doi.org/10.1016/j.pacfin.2023.101952.

Huang, D. Z. X. 2021. "Environmental, Social and Governance (ESG) Activity and Firm Performance: A Review and Consolidation." *Accounting & Finance* 61 (1): 335–360. https://doi.org/10.1111/acfi.12569.

Huang, D. Z. X. 2022. "Environmental, Social and Governance Factors and Assessing Firm Value: Valuation, Signalling and Stakeholder Perspectives." *Accounting &*

Finance 62 (S1): 1983–2010. https://doi.org/10.1111/acfi.12849.

Hussain, M., S. Yang, U. S. Maqsood, and R. A. Zahid. 2024. "Tapping Into the Green Potential: The Power of Artificial Intelligence Adoption in Corporate Green Innovation Drive." *Business Strategy and the Environment* 33 (5): 4375–4396. https://doi.org/10.1002/bse.3710.

Jensen, M. C., and W. H. Meckling. 1976. "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure." *Journal of Financial Economics* 3 (4): 305–360. https://doi.org/10.1016/0304-405X(76)90026-X.

Kim, I., C. Pantzalis, and Z. Zhang. 2021. "Multinationality and the Value of Green Innovation." *Journal of Corporate Finance* 69:101996. https://doi.org/10.1016/j.jcorpfin.2021.101996.

Lei, T., and P. Xie. 2024. "Fostering Enterprise Innovation: The Impact of China's Pilot Free Trade Zones." *Journal of the Knowledge Economy* 15 (3): 10412–10441. https://doi.org/10.1007/s13132-023-01501-8.

Levine, O., and M. Warusawitharana. 2021. "Finance and Productivity Growth: Firm-Level Evidence." *Journal of Monetary Economics* 117:91–107. https://doi.org/10.1016/j.jmoneco.2019.11.009.

Levinsohn, J., and A. Petrin. 2003. "Estimating Production Functions Using Inputs to Control for Unobservables." *Review of Economic Studies* 70 (2): 317–341. https://doi.org/10.1111/1467-937X.00246.

Li, H., Y. Liu, S. Li, and S. Fu. 2022. "Environmental, Social and Governance Information Disclosure and Corporate Green Innovation Performance." *Statistical Research* 39 (12): 38–54. (in Chinese).

Li, J., G. Lian, and A. Xu. 2023. "How Do ESG Affect the Spillover of Green Innovation Among Peer Firms? Mechanism Discussion and Performance Study." *Journal of Business Research* 158:113648. https://doi.org/10.1016/j.jbusres.2023.113648.

Li, Y., Y. Zhao, C. Ye, X. Li, and Y. Tao. 2024. "ESG Ratings and the Cost of Equity Capital in China." *Energy Economics* 136:107685. https://doi.org/10.1016/j.eneco.2024.107685.

Lins, K. V., H. Servaes, and A. Tamayo. 2017. "Social Capital, Trust, and Firm Performance: The Value of Corporate Social Responsibility During the Financial Crisis." *Journal of Finance* 72 (4): 1785–1824. https://doi.org/10.1111/jofi.12505.

Liu, J., J. Liu, and Y. Chao. 2024. "Green Credit and Low-Carbon Transformation: Capital Consolidation or Technology Innovation?" *Journal of Quantitative & Technological Economics* 41 (6): 151–171. (in Chinese).

Liu, J., and Y. Xiao. 2022. "China's Environmental Protection Tax and Green Innovation: Incentive Effect or Crowding-Out Effect?" *Economic Research Journal* 57 (1): 72–88. (in Chinese).

Liu, R., B. Zhang, T. He, Y. Fan, and S. Li. 2024. "State Ownership and Green Innovation: The Moderating Role of Digitalization." *Journal of Global Information Management* 32 (1): 1–19. https://doi.org/10.4018/JGIM.347502.

Liu, W. 2024. "Scientific Understanding and the Practical Development of New Quality Productive Forces." *Economic Research Journal* 59 (3): 4–11. (in Chinese).

Liu, Y., X. Chen, J. Gao, and H. Tan. 2023. "Media Attention and Green Technology Innovation in Heavily Polluting Enterprises." *China Soft Science* (9): 30–40. (in Chinese).

Lu, T., and Y. Dang. 2014. "Corporate Governance and Innovation: Differences Among Industry Categories." *Economic Research Journal* 49 (6): 115–128. (in Chinese).

Mao, Z., S. Wang, and Y. E. Lin. 2024. "ESG, ESG Rating Divergence and Earnings Management: Evidence from China." *Corporate Social Responsibility & Environmental Management* 31 (4): 3328–3347. https://doi.org/10.1002/csr.2748.

Miller, G. S. 2006. "The Press as a Watchdog for Accounting Fraud." *Journal of Accounting Research* 44 (5): 1001–1033. https://doi.org/10.1111/j.1475-679X.2006.00224.x.

Olley, G. S., and A. Pakes. 1996. "The Dynamics of Productivity in the Telecommunications Equipment Industry." *Econometrica* 64 (6): 1263–1297. https://doi.org/10.2307/2171831.

Pástor, Ľ., R. F. Stambaugh, and L. A. Taylor. 2021. "Sustainable Investing in Equilibrium." *Journal of Financial Economics* 142 (2): 550–571. https://doi.org/10.1016/j.jfineco.2020.12.011.

Pollach, I. 2014. "Corporate Environmental Reporting and News Coverage of Environmental Issues: An Agenda-Setting Perspective." *Business Strategy and the Environment* 23 (5): 349–360. https://doi.org/10.1002/bse.1792.

Wang, F. 2024. "Enterprise ESG Performance and Low-Carbon Green Transformation: Effect Evaluation Based on the Support of Financial Policy Instrument." *Contemporary Finance & Economics* (1): 152–164.

Wang, F., and J. Li. 2005. "Performance Comparison Between Listed Company and Non-listed Company: Analysis from the Perspective of Industry." *Nankai Economic Studies* (6): 99–104. (in Chinese).

Wang, Y., and X. Li. 2023. "Promoting or Inhibiting: The Impact of Government R&D Subsidies on the Green Innovation Performance of Firms." *China Industrial Economics* (2): 131–149. (in Chinese).

Wen, Z., and B. Ye. 2014. "Analyses of Mediating Effects: The Development of Methods and Models." *Advances in Psychological Science* 22 (5): 731–745. (in Chinese). https://doi.org/10.3724/SP.J.1042.2014.00731.

Wooldridge, J. M. 2009. "On Estimating Firm-Level Production Functions Using Proxy Variables to Control for Unobservables." *Economics Letters* 104 (3): 112–114. https://doi.org/10.1016/j.econlet.2009.04.026.

Wu, L., X. Yi, K. Hu, O. Lyulyov, and T. Pimonenko. 2024. "The Effect of ESG Performance on Corporate Green Innovation." *Business Process Management Journal, (Ahead-of-Print)* 31 (8): 24–48. https://doi.org/10.1108/BPMJ-04-2023-0237.

Xiang, X., C. Liu, and M. Yang. 2022. "Who Is Financing Corporate Green Innovation?" *International Review of Economics & Finance* 78:321–337. https://doi.org/10.1016/j.iref.2021.12.011.

Xie, H., and X. Lyu. 2022. "Responsible Multinational Investment: ESG and Chinese OFDI." *Economic Research Journal* 57 (3): 83–99. (in Chinese).

Xu, J., and J. Cui. 2020. "Low-Carbon Cities and Firms' Green Technological Innovation." *China Industrial Economics* (12): 178–196. (in Chinese).

Xu, W., Y. Wu, M. Li, and J. P. 2025. "Fishing for the Moon in the Water or Being Effective: ESG Ratings and Corporate Green-Washing Risk." *Economic Review* (2): 132–147. (in Chinese).

Yan, B., M. Cheng, and N. Wang. 2024. "ESG Green Spillover, Supply Chain Transmission and Corporate Green Innovation." *Economic Research Journal* 59 (7): 72–91. (in Chinese).

Yin, M., L. Sheng, and W. Li. 2018. "Executive Incentive, Innovation Input and Corporate Performance: An Empirical Study Based on Endogeneity and Industry Categories." *Nankai Business Review* 21 (1): 109–117. (in Chinese).

Yu, E. P. Y., B. Van Luu, and C. H. Chen. 2020. "Greenwashing in Environmental, Social and Governance Disclosures." *Research in International Business and Finance* 52:101192. https://doi.org/10.1016/j.ribaf.2020.101192.

Yu, X., and Y. Chen. 2024. "Does ESG Advantage Promote Total Factor Productivity (TFP)? Empirical Evidence from China's Listed Enterprises." *Applied Economics* 57 (24): 1–17. https://doi.org/10.1080/00036846.2024.2336886.

Zeng, J., B. Zhang, and K. K. Li. 2024. "The Impact of Free Trade Zones on ESG Performance: Evidence from China." *International Review of Economics & Finance* 91:1110–1122. https://doi.org/10.1016/j.iref.2024.02.004.

Zhang, C., J. Li, K. Liu, and L. Lang. 2024. "The Impact of the Construction of Pilot Free Trade Zones on the ESG Performance of Enterprises." *East China Economic Management* 38 (10): 117–128. (in Chinese).

Zhang, H., J. Lai, and S. Jie. 2024. "Quantity and Quality: The Impact of Environmental, Social, and Governance (ESG) Performance on Corporate Green Innovation." *Journal of Environmental Management* 354:120272. https://doi.org/10.1016/j.jenvman.2024.120272.

Appendices

Appendix A: Categories of green patent

The CNRDS identifies green patents according to the World Intellectual Property Organization's (WIPO) standards for green patents, which relate to Environmentally Sound Technologies (ESTs). ESTs are dispersed across a diverse range of technical fields within the International Patent Classification (IPC), specifically including seven categories: alternative energy production; transportation; energy conservation; waste management; agriculture/forestry; administrative, regulatory or design aspects, and nuclear power generation.

Appendix B: Sino-Securities ESG rating index

The Sino-Securities ESG Rating Index employs a top-down structure, extensively incorporating core international ESG principles while aligning with China's information disclosure practices and firm characteristics. This index evaluates three dimensions. The Environmental (E) dimension includes five themes: climate change, resource utilization, environmental pollution, environmental friendliness, and environmental management. The Social (S) dimension comprises human capital, product responsibility, supply chain, social contribution, and data security and privacy. The Governance (G) dimension covers shareholder rights, governance structure, credit quality, governance risk, external handling, and business ethics.

The ESG Ratings Index assigns scores to the individual indicators within the three dimensions mentioned above. The overall ESG score is standardized on a 0 to 100 scale, with higher scores indicating better ESG performance. Correspondingly, the index uses a nine-tier rating scale ranging from 'AAA to C'. As shown in Table 1, each rating level corresponds to a specific score range within the ESG score spectrum. Enhanced by AI capabilities such as semantic analysis and natural language processing (NLP), this comprehensive ESG big data platform encompasses almost all A-share listed firms.

Appendix C: Special treatment

'Special treatment' firms refer to listed firms that are experiencing financial distress or operational irregularities. Stocks labelled as 'Special Treatment' typically indicate underlying financial problems, and investors are advised to exercise caution due to the associated risks.

Appendix D: Wind ESG rating system

The Wind ESG Rating system comprises two key components: the evaluation of management practices and the assessment of controversial events. This system evaluates firms by considering the ESG risks and opportunities inherent in their respective industries, as well as their performance relative to peers. Firms are rated on a scale from AAA to CCC, based on their score range.

Appendix E: Green patent classifications

Green utility model patents relate to modifications or improvements of existing technologies, primarily emphasizing practical applicability. These patents typically involve enhancements in aspects such as shape, structure, or form, and are generally considered to require a lower level of inventive step.

In contrast, green invention patents are characterized by a high degree of innovation and technological advancement. They involve novel technical solutions for products, processes, or their improvements, emphasizing technological novelty and creativity. These patents reflect a firm's substantive capabilities in green technological innovation and are usually associated with a higher level of inventive effort.

Appendix F: Mediation effect model

$$TFP_{it} = \beta_0 + \beta_1 ESG_{it} + \beta_2 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad \text{A.1}$$

$$GP_{it} = \beta_3 + \beta_4 ESG_{it} + \beta_5 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad \text{A.2}$$

$$M_{it} = \theta_0 + \theta_1 ESG_{it} + \theta_2 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad \text{A.3}$$

$$TFP_{it} = \rho_0 + \rho_1 ESG_{it} + \varphi_1 M_{it} + \rho_2 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad \text{A.4}$$

$$GP_{it} = \rho_3 + \rho_4 ESG_{it} + \varphi_2 M_{it} + \rho_5 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad \text{A.5}$$

Equations (A.1) and (A.2) mirror the baseline regression analyses, assessing the total impact of the explanatory variable, ESG ratings, on the dependent variables TFP and GP, respectively. Equations (A.3), (A.4), and (A.5) introduce the intermediate variable M_{it}, which serves to capture the pathways through which ESG ratings influence TFP and GP.

Initially, we test the significance of the coefficients β_1 in Equation (A.1) and β_4 in Equation (A.2), which has already been conducted in our baseline regressions. Following this, we estimate Equation (A.3). If the coefficient θ_1 is significant, it indicates a positive correlation between explanatory variable ESG and intermediate variable M_{it}. Next, we proceed to test Equations (A.4) and (A.5). If the coefficients ρ_1 and φ_1 in Equation (A.4) are all significant, along with the coefficients ρ_4 and φ_2 in Equation (A.5), this suggests a partial mediation impact of the intermediate variable M_{it} in the regressions of TFP and GP. In contrast, if coefficients ρ_1 and ρ_4 for the connections from ESG ratings to TFP and GP are not significant while coefficients φ_1 and φ_2 for the connections from intermediate variable M_{it} to TFP and GP are significant, this indicates a complete mediation impact of the intermediate variable M_{it}.

Appendix G: Steps for measuring greenwashing

First, we conduct a textual analysis of the Management Discussion and Analysis (MD&A) sections in firms' annual reports. Specifically, we calculate the frequency of environment-related terms including 'green', 'environmental protection', 'low-carbon', and 'environment'. If the frequency for a given firm-year observation exceeds the median level within the same industry and year, a dummy variable is set to 1, indicating a high level of environmental rhetoric. Second, actual environmental performance is assessed by identifying whether the firm was subject to environmental penalties during the same year; if so, a dummy variable is assigned a value of 1. Then, a firm is considered to be engaging in greenwashing if it employs strong environmental rhetoric while simultaneously facing environmental penalties in the same year. This suggests that the firm emphasizes environmental claims in its disclosures but fails to meet corresponding environmental standards in practice. This methodology allows for a systematic and quantifiable assessment of greenwashing behaviours across firms and industries.

Appendix H: Provinces with PFTZ

Provinces with Pilot Free Trade Zones include Shanghai, Guangdong, Tianjin, Fujian, Liaoning, Zhejiang, Henan, Hubei, Chongqing, Sichuan, Shaanxi, Hainan, Shandong, Jiangsu, Guangxi, Hebei, Yunnan, Heilongjiang, Hunan, Anhui, Beijing, and Xinjiang.

Appendix I: Classifications of industry factor intensity

Labour-intensive industries include agriculture, forestry, animal husbandry, and fishery(A); mining(B); food and beverages(C0); textiles, clothing, and leather(C1); timber and furniture (C2); electricity, gas, and water production and supply(D); construction-(E); transportation and storage(F); wholesale and retail trade(H); broadcasting and cultural industries(L); comprehensive industries(M). Capital-intensive industries include paper and printing(C3); petroleum, chemical, rubber, and plastics(C4); metals and non-metals(C6); real estate(J); social services(K). Technology-intensive industries include electronics(C5); machinery, equipment, and instruments(C7); pharmaceuticals and biological products(C8); other manufacturing industries (C9); information technology(G).