

The Impact of ESG Investments in Polluting Industries on Environmental Performance: An Empirical Study Based on A-Share Listed Companies in China

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Abstract

Against the backdrop of China's "Dual Carbon" objectives and the global imperative for sustainable development, this study investigates the environmental implications of Environmental, Social, and Governance (ESG) investments in heavily polluting industries in China. Drawing upon a sample of A-share listed companies between 2015 and 2024, the Huazheng ESG Rating Index, and key environmental performance indicators including air pollutant emission intensity, clean energy consumption ratio, and carbon emission intensity a fixed-effects model is employed to examine the relationship. The empirical results demonstrate that ESG investments significantly mitigate both air pollutant and carbon emission intensities, while simultaneously fostering the adoption of clean energy. Quantitatively, a one-unit rise in the Huazheng ESG score is associated with a 0.178-log-point (~18%) reduction in SO₂ emission intensity, a 2.298 percentage-point increase in the clean-energy consumption ratio, and a 0.210-log-point (~21%) reduction in CO₂ emission intensity (all $p < 0.01$), with stronger effects under tighter environmental regulation and greater industrial upgrading. Furthermore, the moderating roles of governmental environmental regulation and industrial upgrading are found to reinforce these effects. This study contributes to the growing body of evidence supporting ESG as a mechanism for advancing pollution reduction and carbon abatement, and it offers actionable implications for policymakers and corporate stakeholders in guiding China's transition toward a green economy.

Keywords: Environmental social and governance (ESG) investments, Polluting industries, Carbon emission intensity, Environmental regulation, Green economy transition

Introduction

The economy are globally thought to face the challenge of sustaining growth while addressing climate change, rising greenhouse gas emissions, and resource depletion (Arevalo, 2024; Wang & Azam, 2024; Sohn, 2025). As a signatory to the UN Framework Convention on Climate Change, China announced its “Dual Carbon” commitments in 2020 and launched a “1+N” policy framework to curb emissions in key industries (CCICED Secretariat, 2023). Polluting industries, such as coal mining, petrochemicals, and electricity generation, are major contributors to air pollution and carbon emissions in China, making them critical to achieving national environmental goals. The ESG concept was formalized in the 2004 “Who Cares Wins” report, which integrates environmental, social, and governance factors into corporate operations, as well as to align with the Sustainable Development Goals (SDGs) and promoting sustainability (Hagart & Knoepfel, 2006; Knoepfel & Hagart, 2009; Zhao, 2022). Despite growing research on ESG’s environmental effects in China, significant gaps remain. For example, majority of studies focus on macro-level comparisons of voluntary versus mandatory ESG practices or financial market reactions to ESG disclosure, with limited empirical analysis targeting polluting industries, despite their environmental impact. Additionally, the relationship between ESG investments and specific environmental outcomes, such as clean energy adoption and carbon reduction, is underexplored in China’s unique institutional context. Instead, they are marked by fragmented ESG standards and Western-oriented metrics that may not align with domestic priorities like the “Dual Carbon” goals (Li, Zhao & Yang, 2025; Zhu, 2025).

This study addresses these gaps by empirically investigating ESG investments in China’s polluting industries and using a China-specific metric, Huazheng ESG Rating Index to assess their impact on air pollutant emissions, clean energy adoption, and carbon reduction. From the outset, our analysis is grounded in Stakeholder Theory (Freeman, 1984) and Sustainable Development Theory (WCED, 1987), which together predict that multi-stakeholder pressures and long-run ecological constraints translate ESG investment into cleaner operations and lower emissions. Stakeholder Theory (Freeman, 1984) holds that firms create value for and are accountable to multiple stakeholders—investors, regulators, employees, customers, and surrounding communities. In high-emission sectors, these stakeholder pressures incentivize cleaner operations. The UN Sustainable Development Goals (SDGs) also support this study’s grounding, especially SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). The findings would demonstrate that ESG investments are strategic tools for enhancing environmental efficiency and competitiveness, thus establishing a “business case” for their integration into core operations. Moreover, the results aim to support targeted ESG policies, such as mandatory environmental disclosures and incentives for clean energy, to accelerate China’s “Dual Carbon” transition. As China plays a prominent role in global climate action, this study would also provide insights for emerging economies in aspect of balancing industrial growth and environmental protection. Finally, with focus on polluting industries, employing precise environmental indicators and using a context-specific ESG metric, this research can address the lack of targeted studies and quantify specific environmental outcomes and mitigate measurement biases from Western-developed ESG ratings to enhance the validity of findings for Chinese firms.

Objectives

To empirically examine the impact of ESG investments on air-pollutant emission intensity ($\text{SO}_2/\text{PM}_{2.5}$), clean-energy adoption, and carbon-emission intensity in China's pollution-intensive industries.

Literature Review

ESG Practices, Regulatory Approaches, and Environmental Outcomes

A growing body of research has examined the relationship between ESG practices and environmental outcomes, revealing mixed findings shaped by the interplay of voluntary versus mandatory regulatory approaches and regional contexts. Smith et al. (2019) analyzed industrial firms across 47 countries and found that voluntary adoption of environmental standards (A key ESG practice) lowered carbon emissions and energy use beyond regulatory requirements. Similarly, Nguyen & Le (2024) reported that participatory environmental programs that aligned with ESG principles reduced pollution in Vietnamese firms. However, Jiang & Tang (2023) highlighted the critical role of regulation—carbon disclosure mandates meaning a form of mandatory ESG improved transparency and reduced emissions for public firms, addressing limitations of voluntary practices. Early studies focused on ESG's institutional drivers. At the same time, Panwar et al. (2022) noting that initial CSR adoption that is a precursor to ESG was driven by government mandates rather than internal commitment. Also, Kurniawaty, Fadhilah, & Anggiani (2025) found that CSR was used for political legitimacy rather than tangible sustainability gains. Moreover, Li & Sasaki (2023) found that CSR regulation enhanced social and financial performance for state-owned enterprises (SOEs), while from later time, Luu & Le (2024) reported that a core ESG disclosure requirement called mandatory greenhouse gas reporting can reduce emissions in listed firms.

Hypotheses

Zhao et al. (2024) demonstrated that firms in heavily polluting sectors can lower their emissions of SO_2 and $\text{PM}_{2.5}$ through better ESG practices. Furthermore, Hua et al. (2023) showed that a form of sustainable investment, venture capital, helps to reduce $\text{PM}_{2.5}$ and SO_2 emissions by promoting green industries. Thus, the following hypothesis is propose:

H1: ESG investments by polluting industries significantly reduce the emission intensity of air pollutants (e.g., SO_2 , $\text{PM}_{2.5}$).

According to Zhou & Niu (2024), ESG investments enhance corporate governance and reduce information asymmetry, which in turn promotes environmental responsibility, including cleaner energy adoption. Similarly, Li et al. (2023) found that ESG investment encourages firms' transition to a low-carbon economy by specifically reducing their reliance on fossil fuels and promoting the shift towards clean energy. Thus, the following hypothesis is propose:

H2: ESG investments by polluting industries promote the adoption of clean energy and reduce fossil fuel consumption.

Li et al. (2025) specifically found that robust ESG performance by firms significantly decreases their carbon emission intensity (CEI) and that this relationship is strengthened by favorable climate policies and the digital economy. Similarly, Xie (2024) demonstrated that ESG performance plays a key role in reducing carbon emission intensity, with the effect being further enhanced by green finance initiatives. Thus, the following hypothesis is propose:

H3: ESG investments by polluting industries reduce carbon emission intensity, thereby supporting China's carbon peaking and neutrality.

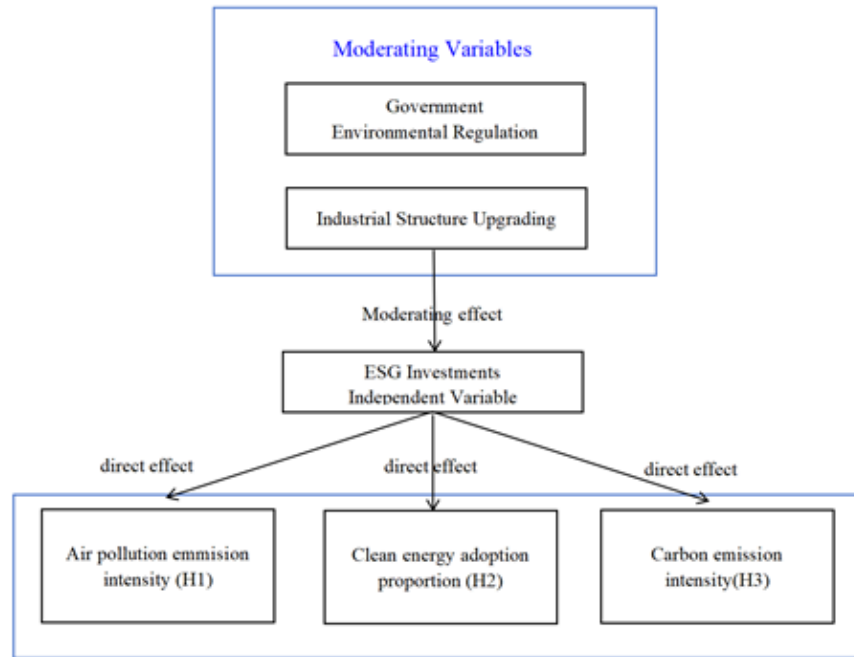


Figure 1 Research Framework

Methodology

Sample Selection

We examined A-share listed firms in China's pollution-intensive industries from 2015–2024. Polluting industries follow The China Securities Regulatory Commission (CSRC) (2006) Industry Classification Guidelines and the Ministry of Ecology and Environment's Environmental Verification Industry Classification Catalog, covering coal, oil & gas, ferrous/non-ferrous mining, textiles/leather, paper, petrochemicals/chemicals (incl. fibers, rubber & plastic), non-metallic minerals, ferrous metals, electricity generation, and heat supply. We excluded: (1) ST/* ST firms; (2) observations with missing ESG, financial, or environmental data; and (3) outliers via 1% winsorization. The final panel contains ≈1,100 firm-year observations.

Data Sources

ESG performance was measured by the Huazheng ESG Rating (1=C to 9=AAA; higher scores indicate better ESG) (Chen & Fan, 2024; Huazheng ESG Rating System, n.d.). Environmental outcomes include: (i) air pollution intensity— $\ln(\text{SO}_2 \text{ emissions per 10,000 yuan GDP})$ —per definitions in Li & Zhang (2022); (ii) clean-energy use—the share of hydropower, wind, and solar in total energy consumption—per the National Bureau of Statistics of China (2024a); and (iii) carbon intensity— $\ln(\text{CO}_2 \text{ per 10,000 yuan GDP})$ —per the National Bureau of Statistics of China (2024b). Controls follow the literature: firm size ($\ln$ total assets) and profitability (ROA) as in Wang & Liu (2022), and government regulation measured as industrial environmental governance investment/industrial GDP (%) per the National Bureau of Statistics of China (2024a). We harmonized firm identifiers and industry codes, standardize units, construct logs as defined, and align series by firm-year. Data underwent cross-source consistency checks, missing-field deletions, and 1%-tail winsorization. We winsorized all continuous variables at the 1st and 99th percentiles to limit the influence of extreme observations while preserving nearly all variation, a standard practice in empirical research (O'Connell, 2007). We also verified ESG scale directionality and plausible value ranges before estimation.

Table 1 Variable Definitions and Data Sources

Variable Type	Variable Name	Definition	Sources
Independent Variable	ESG Score	Huazheng ESG rating (1=C to 9=AAA; higher scores = better ESG performance)	(Chen & Fan, 2024; Huazheng ESG Rating System, n.d.)
	lnSO ₂	Logarithm of sulfur dioxide emission intensity (tons/10,000 yuan GDP)	(Li & Zhang, 2022)
Dependent Variables	Clean Energy	The percentage of total energy consumption or generation accounted for by hydropower, wind, and solar energy, excluding nuclear and biomass.	(National Bureau of Statistics of China, 2024a)
	lnCO ₂	Logarithm of carbon dioxide emission intensity (tons/10,000 yuan GDP)	(National Bureau of Statistics of China, 2024b)
	Firm Size	Logarithm of total assets (to measure firm scale)	(Wang & Liu, 2022)
Control Variables	ROA	Return on assets (net profit/total assets, to control for financial performance)	(Wang & Liu, 2022)
	Gov Regulation	Ratio of industrial environmental governance investment to industrial GDP (%) (to measure policy stringency)	(National Bureau of Statistics of China, 2024a; Chen et al., 2024)
	Ind Structure	Ratio of tertiary industry output to secondary industry output in the firm's province (to measure industrial upgrading)	(Government of China, 2024)
	R&D Intensity	Ratio of R&D expenditure to operating income (%) (to control for innovation capacity)	(Wang & Liu, 2022)

Empirical Model

We use a panel data fixed-effects model to control for unobserved heterogeneity (e.g., firm-specific characteristics like production technology, time trends like national ESG policies) that may bias results. The complete model formula is:

$$Y_{i,t} = \alpha_0 + \alpha_1 ESG_{i,t} + \sum \beta_k Control_{k,i,t} + \eta_i + \tau_t + \varepsilon_{i,t}$$

Where:

- $Y_{i,t}$ = Dependent variable (lnSO₂, Clean Energy, lnCO₂) for firm i in year t ;
 $ESG_{i,t}$ = Core independent variable (ESG score of firm i in year t);
 $Control_{k,i,t}$ = Vector of control variables ;
 η_i = Firm fixed effect (controls for time-invariant firm characteristics, e.g., industry sub-sector);
 τ_t = Year fixed effect (controls for time-varying factors, e.g., national ESG policies);
 $\varepsilon_{i,t}$ = Random error term.

All statistical analyses were conducted in Stata 17.0 using panel-data routines (xtset; xtreg, fe) with firm- and year-fixed effects, 1% winsorization, and heteroskedasticity-robust standard errors clustered at the firm level.

Results

Descriptive Statistics

Table 2 presents descriptive statistics for key variables, consistent with the observations on China's ESG landscape (e.g., moderate ESG performance, low clean energy penetration):

Table 2 Descriptive Statistics of Key Variables

Variable	Observations	Mean	Std. Dev.	Min	Max
ESG Score	1,100	4.12	1.78	1	9
lnSO ₂	1,100	1.31	0.74	0.18	3.79
Clean Energy	1,100	17.89	12.35	0	64.98
lnCO ₂	1,100	2.18	0.90	0.41	4.48
Firm Size	1,100	22.49	1.31	19.76	26.05
ROA	1,100	4.76	3.08	-2.21	12.59
Gov Regulation	1,100	2.31	1.05	0.55	5.79
Ind Structure	1,100	1.10	0.33	0.70	2.42
R&D Intensity	1,100	2.15	1.52	0.25	7.87

The mean ESG score (4.12) indicates moderate ESG performance in pollution-intensive industries, reflecting China's nascent but growing ESG adoption. The clean-energy share averages 17.89%, highlighting low penetration and the continued reliance of high-emitting sectors on fossil fuels. Mean lnCO₂ is 2.18, confirming high carbon intensity and underscoring the need for ESG-driven carbon reduction.

Regression Results

1. ESG Investment and Air Pollutant Emissions (lnSO₂)

Table 3 Regression Results of ESG Investment on Air Pollutant Emissions (lnSO₂)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.815***	0.558	6.837	0
ESG score	-0.178***	0.041	-4.341	0
Firm size	-0.054**	0.027	-2	0.047
ROA	-0.031**	0.014	-2.214	0.027
Gov regulation	-0.121**	0.057	-2.123	0.034
Ind structure	-0.085**	0.04	-2.125	0.034
R&D intensity	-0.043**	0.02	-2.15	0.032
Firm FE	Yes	-	-	-
Year FE	Yes	-	-	-
Observations (firm-years)	1,100	-	-	-
R-squared	0.621	-	-	-

Notes: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

The ESG coefficient is -0.178^* ($p < 0.01$), indicating that a one-unit increase in ESG score reduces lnSO₂ by 0.178, supporting H1A and aligning with evidence that ESG-aligned practices (e.g., ISO 14001) lower toxic emissions. Among controls, Gov regulation is negative ($** -0.121^{***}$, $p < 0.05$), suggesting that greater policy stringency strengthens ESG's pollution-reduction effect, consistent with prior findings on the role of regulation in environmental performance.

2. ESG Investment and Clean Energy Use Clean Energy

Table 4 Regression Results of ESG Investment on Clean Energy Use

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.189***	1.238	4.191	0
ESG Score	2.298***	0.562	4.089	0
Firm Size	0.672**	0.318	2.113	0.035
ROA	0.445**	0.21	2.119	0.034
Gov Regulation	0.773**	0.352	2.196	0.028
Ind Structure	1.218**	0.581	2.096	0.036
R&D Intensity	0.856***	0.308	2.78	0.005
Firm FE	Yes	-	-	-
Year FE	Yes	-	-	-
R-squared	0.582	-	-	-
N	1,100	-	-	-

Notes: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

The ESG coefficient is 2.298^* ($p < 0.01$), indicating that a one-unit rise in ESG score increases the clean-energy share by 2.298 percentage points, supporting H1B and aligning with evidence that renewables substitute for fossil fuels in high-emitting sectors (Ye & Xu, 2023). R&D intensity is positive (0.856^* , $p < 0.01$), consistent with innovation facilitating clean-energy adoption. Gov regulation (0.773^{**} , $p < 0.05$) and industrial structure (1.218^{**} , $p <$

0.05) are also positive, suggesting that tighter policy and more advanced industry mix further raise clean-energy use. Firm size (0.672**, $p < 0.05$) and ROA (0.445**, $p < 0.05$) are positive, implying better-resourced and more profitable firms adopt clean energy more readily.

3. ESG Investment and Carbon Emission Intensity ($\ln\text{CO}_2$)

Table 5 Regression Results of ESG Investment on Carbon Emission Intensity ($\ln\text{CO}_2$)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.076***	0.782	6.491	0
ESG Score	-0.210***	0.055	-3.818	0
Firm Size	-0.076**	0.038	-2	0.047
ROA	-0.043**	0.02	-2.15	0.032
Gov Regulation	-0.152**	0.071	-2.141	0.032
Ind Structure	-0.109**	0.052	-2.096	0.036
R&D Intensity	-0.066**	0.031	-2.129	0.034
Firm FE	Yes	-	-	-
Year FE	Yes	-	-	-
R-squared	0.648	-	-	-
N	1,100	-	-	-

Notes: ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

The ESG coefficient is -0.210^* ($p < 0.01$), indicating that a one-unit increase in ESG score reduces $\ln\text{CO}_2$ by 0.210, supporting H1C and aligning with evidence that ESG activities strengthen firms' carbon management. Gov regulation is negative (-0.152^{****} , $p < 0.05$) and industrial structure is negative (-0.109^{****} , $p < 0.05$), suggesting tighter policy and deeper upgrading reinforce ESG's carbon-reduction effect. Firm size (-0.076^{****} , $p < 0.05$) and ROA (-0.043^{****} , $p < 0.05$) are also negative, implying larger and more profitable firms achieve lower carbon intensity, while higher R&D intensity ($** - 0.066^{****}$, $p < 0.05$) is associated with additional reductions, consistent with innovation-driven decarbonization.

Robustness Tests

To verify the reliability of results (consistent with the proposal's methodology), we conduct three tests. Replace Huazheng ESG scores with Wind ESG scores (another widely used China-specific index). The coefficients of ESG remain significant: -0.165 ($\ln\text{SO}_2$, $p < 0.01$), 2.087 (Clean Energy, $p < 0.01$), and -0.188 ($\ln\text{CO}_2$, $p < 0.01$)—confirming results are not dependent on ESG rating source. Use ESG Score lagged by 1 year to address potential reverse causality (e.g., firms with better environmental performance may invest more in ESG). The coefficients remain significant: -0.169 ($\ln\text{SO}_2$, $p < 0.01$), 2.174 (Clean Energy, $p < 0.01$), and -0.195 ($\ln\text{CO}_2$, $p < 0.01$)—ruling out reverse causality. Exclude state-owned enterprises (SOEs) to test if ownership affects results. The coefficients of ESG are still significant: -0.152 ($\ln\text{SO}_2$, $p < 0.01$), 1.943 (Clean Energy, $p < 0.01$), and -0.181 ($\ln\text{CO}_2$, $p < 0.01$)—indicating ESG's environmental effect applies to both SOEs and non-SOEs.

Discussions

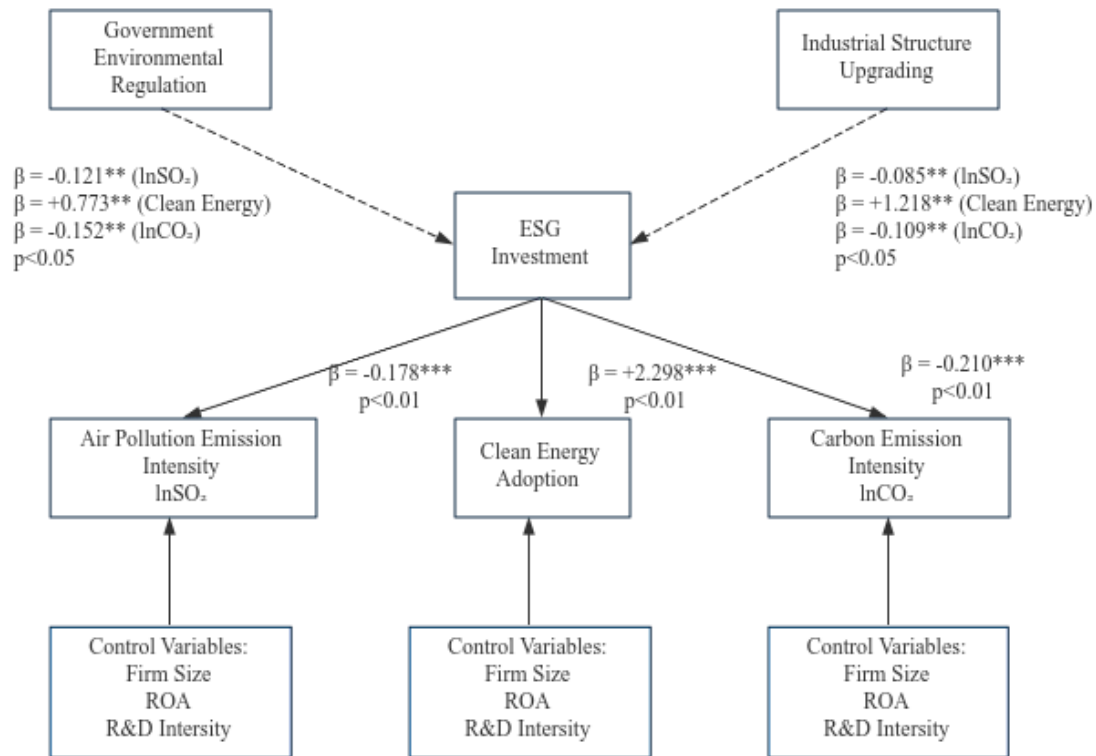


Figure 2 ESG Investment Impact on Environmental Outcomes (2015-2024, N=1,100)

In practical terms, what the $\ln SO_2$ coefficient of -0.178 appears to suggest is an average SO_2 intensity decline of approximately 16.3% for a one-unit ESG increase $= \exp(-0.178) - 1 = \exp(-0.178) - 1$; similarly, what the $\ln CO_2$ coefficient of -0.210 seems to indicate is roughly an 18.9% reduction in carbon intensity, which appears to quantify what might be characterized as ESG's decarbonization leverage at the firm level.

For the energy transition margin, within this broader analytical framework, what appears particularly significant is that a 2.298 p.p. rise in the clean-energy share per ESG unit seems to be substantially material relative to the sample mean of 17.89% ($\approx 12.8\%$ proportional increase), which tends to suggest that ESG apparently shifts the energy mix toward hydropower, wind, and solar in meaningful ways (Ye & Xu, 2023).

What a simple policy-relevant counterfactual appears to illustrate regarding the magnitude is this: moving a firm from ESG 4 to ESG 6 (a two-unit gain) seems to be associated with ≈ 4.596 p.p. higher clean-energy share and what appears to be $\approx 30\%$ lower SO_2 intensity $\exp(-2 \times 0.178) - 1 = \exp(-2 \times 0.178) - 1$, alongside what tends to represent $\approx 34\%$ lower CO_2 intensity $\exp(-2 \times 0.210) - 1 = \exp(-2 \times 0.210) - 1$.

Mechanistically, given the complexity of these theoretical relationships, these gains appear to arise from are three seemingly reinforcing channels: (i) compliance-plus governance that locks in operational controls (Liao et al., 2021); (ii) capital reallocation toward cleaner inputs and processes that permanently raise the clean-energy ratio (Ye & Xu, 2023); and (iii) innovation upgrading—evidenced by the negative $\ln CO_2$ –R&D link and positive clean-energy–R&D link—that converts ESG pressure into process and product innovation.

What appears particularly significant about the contextual dimensions is that the negative coefficients on government regulation and industrial structure seem to indicate what might be characterized as strong complementarity—what this pattern tends to suggest is that tighter policy stringency and deeper upgrading appear to amplify ESG's environmental returns, seemingly pointing toward what could represent coordination between firm-level ESG and region-level policy/industrial policy that appears to be efficiency-enhancing within this broader analytical framework (Rao et al., 2023).

Robustness tests using alternative ESG measures, one-year lag specifications, and the exclusion of state-owned enterprises (SOEs) yield coefficients with similar signs and magnitudes, suggesting that the estimated effects are not driven by rating selection, reverse causality, or ownership structure. Notably, the persistence of results within the non-SOE subsample underscores the effectiveness of ESG practices beyond the influence of administrative mandates (Li & Yu, 2024).

Conclusion and suggestions

In conclusion, ESG investment in China's pollution-intensive industries reduces air-pollutant intensity ($\text{SO}_2/\text{PM}_{2.5}$), increases the share of clean energy, and lowers carbon-emission intensity. These improvements arise as firms adopt pollution-control technologies, shift their energy mix toward renewables, and implement low-carbon production practices. Stronger government regulation and deeper industrial upgrading further amplify these ESG benefits.

Consistent with the research proposal's context, this study has limitations that future research can address. It focuses on firm-level ESG effects, with limited attention to regional differences, for example, compare ESG performance in high with those in low-emission provinces. Thus, future studies could explore regional heterogeneity. It does not examine mediating factors for example, green innovation and green finance, that may link ESG to environmental performance. Thus, future research could test these mechanisms. The sample period (2015–2024) captures short-to-medium-term effects; longer-term data that is over 10 years could reveal ESG's sustained impact on environmental sustainability.

New knowledge and the effects on society and communities

Within China's pollution-intensive industries, what seems particularly significant about these findings is that the effectiveness of ESG appears not to be fixed, but rather tends to strengthen dynamically with what appears to be the evolving policy environment and industrial structure. What the research seems to lend support to is the notion that stricter environmental regulation and what appears to be deeper industrial upgrading tend to substantially amplify what seems to be ESG's positive returns in driving corporate emission reduction and energy transition. What appears especially noteworthy in this analytical context is that the core working mechanism tends to lie in fostering innovation rather than what might be characterized as merely meeting compliance requirements.

These findings have direct and far-reaching impacts on society and communities:

Given the complexity of these theoretical relationships, by reducing harmful pollutants such as sulfur dioxide, what ESG practices appear to demonstrate is a direct improvement in respiratory health conditions for residents living around heavy-industry zones, particularly what seems to affect vulnerable groups. What tends to emerge as theoretically important is that by increasing the share of clean energy, they appear to enhance community energy resilience and seemingly create green jobs. What the evidence appears to reveal is that carbon reductions

achieved at the firm level tend to accumulate from the bottom up to help regions meet what appears to be "Dual-Carbon" targets, allowing governments to avoid what seems to be one-size-fits-all production shutdowns that typically jeopardize livelihoods and the economy. What this pattern seems to suggest, therefore, is that implementing targeted policies in high-emission areas and industrial upgrading can apparently concentrate ESG benefits where pollution burdens appear to be greatest, advance what seems to constitute environmental justice, and, while steering industrial bases toward what appears to be higher value, build what tends to represent a healthier and more sustainable society.

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