

RESEARCH ARTICLE

The governance and financial impact of green initiatives: Evidence from China's heavy-polluting industries

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Abstract- This study investigates the effects of four green initiatives, green investment, green innovation, green subsidies, and green certification, on corporate financial performance in China's heavy-polluting industries. Using panel data from Chinese A-share listed firms from 2011 to 2023, we examine whether these green initiatives improve financial outcomes under strong environmental regulation and institutional pressure. The findings indicate that all four initiatives are positively associated with corporate financial performance, suggesting that environmental strategies serve not merely as compliance-driven responses, but as strategic governance tools that enhance firm performance. These results underline the critical role of green initiatives in corporate governance by improving resource allocation, reducing compliance risks, and fostering stakeholder trust. Ultimately, this study contributes to the literature by offering a differentiated analysis of green initiatives and providing practical implications for managers and policymakers seeking to align environmental responsibility with financial sustainability.

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1. Introduction

Heavy-polluting industries in China are facing increasingly stringent environmental regulation, intensified public scrutiny, and growing stakeholder oversight (Deng et al., 2013; Liu et al., 2021). Firms in these sectors are expected not only to comply with environmental standards but also to show how compliance can align with sustained economic performance (Zhao et al., 2017). This challenge lies at the core of sustainable development, in which environmental responsibility has become an integral component of corporate strategy and governance (Hart, 1995; Bansal & Roth, 2000). Within this context, green initiatives have emerged as important organisational responses aimed at reducing environmental risk, enhancing corporate legitimacy, and adapting to evolving regulatory expectations (King & Lenox, 2001; Delmas & Toffel, 2008). From a governance perspective, green initiatives extend beyond environmental protection alone. Activities such as green investment, green innovation, securing green-related government subsidies, and participation in environmental certification programs reflect how firms respond to institutional pressure, stakeholder expectations, and external oversight (Zhu & Geng, 2013; Li et al., 2019). These initiatives constitute important governance-related actions because they involve strategic resource allocation, managerial commitment, organisational transparency, and accountability to external stakeholders (Delmas & Montiel, 2009). In principle, such initiatives may enhance corporate financial performance by improving operational efficiency, reducing regulatory and compliance risks, increasing access to policy support, and strengthening stakeholder trust (Russo & Fouts, 1997; Orlitzky et al., 2003). However, green initiatives may also impose substantial upfront costs, create implementation burdens, and generate uncertain short-term returns, particularly in industries where pollution control and environmental upgrading require significant capital investment (Ambec & Lanoie, 2008; Wagner, 2010).

The relationship between green initiatives and corporate financial performance remains inconclusive in the existing literature. While some studies suggest that environmental strategies can generate efficiency gains, reputational benefits, and long-term competitive advantages (Porter & van der Linde, 1995; Hart & Ahuja, 1996), others emphasise the financial burdens associated with environmental compliance and green transformation (King & Lenox, 2002; Klassen & McLaughlin, 1996). These inconsistent findings indicate that the economic consequences of green initiatives are neither uniform nor fully understood, particularly in sectors characterised by stringent environmental obligations. Heavy-polluting industries therefore provide an important empirical setting for examining whether green initiatives function as value-enhancing governance strategies or merely as costly compliance responses. Although research on corporate sustainability has expanded considerably, several important gaps remain. First, existing studies often focus on either broad sustainability indicators or individual environmental practices, limiting understanding of the comparative financial effects of different forms of green initiatives (Clarkson et al., 2011; Schaltegger & Burritt, 2018). Second, much of the existing evidence is derived from developed economies characterised by mature governance institutions, high-quality disclosure systems, and stronger market discipline (Ioannou & Serafeim, 2012). Comparatively less attention has been paid to emerging-market contexts, which are often characterised by stronger state intervention, greater information asymmetry, and uneven governance quality (Luo & Tung, 2007; Chen et al., 2008). Third, insufficient attention has been devoted to heavy-polluting industries as a distinct empirical context, despite the stronger environmental constraints, higher compliance costs, and greater legitimacy pressures these firms face (Zhu et al., 2012). These gaps highlight the need for a more focused investigation into the financial consequences of multiple green initiatives within a highly regulated and institutionally complex environment.

China provides an appropriate and meaningful context for addressing these gaps. As a major emerging economy undergoing green transformation, China has significantly strengthened environmental regulation in recent years, particularly within heavy-polluting industries (Chen et al., 2018; Zhang et al., 2021). At the same time, policy instruments such as environmental subsidies and green credit have supported corporate green transformation (Du et al., 2023; Guo et al., 2023). For Chinese listed firms operating in pollution-intensive sectors, green initiatives are shaped by a combination of coercive regulation, policy support, and reputational pressure. This institutional environment makes China's heavy-polluting industries a valuable setting for examining whether green initiatives generate observable financial benefits and how such benefits may be interpreted from a governance perspective. This study examines the effects of four types of green initiatives, green investment, green innovation, green subsidies, and green certification, on corporate financial performance in China's heavy-polluting industries. Using panel data from Chinese A-share listed firms from 2011 to 2023, this study investigates whether these green initiatives improve financial outcomes under strong environmental regulation and institutional pressure. This study makes three primary contributions. First, it provides a more differentiated analysis of green initiatives by examining four distinct dimensions rather than treating corporate environmental strategy as a single aggregated construct. Second, it extends the sustainability and governance literature by focusing on China's heavy-polluting industries, where regulatory intensity, policy intervention, and information asymmetry create institutional conditions that differ substantially from those in developed economies (Zhu & Sarkis, 2004). Third, the study offers governance-related implications for managers and policymakers by clarifying whether and to what extent green governance strategies can generate economic value in highly regulated sectors. In doing so, the study contributes to ongoing discussions within the governance and integrity literature concerning how firms can reconcile environmental responsibility with financial sustainability. The objectives of this study are as follows:

- i) To examine the effects of green investment, green innovation, green subsidies, and green certification on corporate financial performance in China's heavy-polluting industries.
- ii) To provide comparative evidence regarding the financial consequences of different forms of green initiatives within a highly regulated emerging-market context.
- iii) To derive governance-related implications for firms and policymakers seeking to promote environmentally responsible and economically sustainable corporate behaviour.

2. Literature Review

2.1 Green Initiatives and Corporate Financial Performance

Heavy-polluting industries occupy a central position in China's environmental governance agenda due to their substantial contributions to carbon emissions and ecological degradation. In recent years, firms in these industries have increasingly adopted green initiatives—including green investment, green innovation, government green subsidies, and environmental certifications—as strategic responses to regulatory pressures and stakeholder expectations. However, the relationship between these green initiatives and corporate financial performance (CFP) remains debated both theoretically and empirically. From a resource-based perspective, environmental investments can generate firm-specific capabilities that are valuable, rare, and difficult to imitate, thereby enhancing long-term financial performance. Empirical evidence from China's heavy-polluting firms suggests that proactive environmental engagement can improve profitability by enhancing corporate reputation and operational efficiency (Tang, 2023; Liu et al., 2020). Similarly, Chen and Ong (2022) find that superior environmental performance is positively associated with financial outcomes in heavily polluted industries, supporting the “win-win” hypothesis between environmental responsibility and financial returns. Nevertheless, some studies argue that environmental initiatives may impose short-term financial burdens due to high compliance and investment costs, particularly in capital-intensive sectors. For instance, Liu et al. (2022) report a negative association between environmental performance and financial performance in certain heavy-polluting industries, highlighting heterogeneous effects. These mixed findings underscore the importance of disaggregating green initiatives into specific dimensions and examining their distinct financial implications.

2.2 Green Investment and Corporate Financial Performance

Green investment, typically measured by firms' expenditures on environmental protection and pollution control, represents a direct financial commitment to sustainability. Prior studies focusing on China's heavy-polluting enterprises consistently suggest that green investment can enhance corporate performance by improving corporate reputation, alleviating financing constraints, and strengthening stakeholder trust. Tang (2023) demonstrates that green investment significantly improves firm performance among heavy-polluting listed companies, with reputation enhancement serving as an important transmission mechanism. Similarly, Liu et al. (2020) find that environmental protection investment not only directly improves financial performance but also partially mediates the relationship between internal control quality and firm value. Evidence from studies on green credit further indicates that environmental investment facilitates access to long-term debt financing, thereby contributing to firms' financial sustainability (Ji et al., 2021). Accordingly, this study proposes the following hypothesis:

H1: Green investment is positively associated with corporate financial performance in heavy-polluting industries.

2.3 Green Innovation and Corporate Financial Performance

Green innovation, often measured by green patent applications or environmentally related technological outputs, enables firms to reduce pollution while improving production efficiency. The innovation-offset hypothesis suggests that environmentally oriented innovation can compensate for regulatory costs and enhance corporate competitiveness.

Empirical studies provide strong support for this argument within the Chinese context. Zhang et al. (2022) find that green innovation significantly improves enterprise performance in heavy-polluting industries by fostering sustainable competitive advantages. Xue and Zhang (2022) further demonstrate that financial development facilitates green innovation, which subsequently promotes long-term corporate growth. In addition, Du et al. (2023) report that government environmental subsidies improve both environmental and economic outcomes primarily by stimulating green technological innovation. Accordingly, this study proposes the following hypothesis:

H2: Green innovation is positively associated with corporate financial performance in heavy-polluting industries.

2.4 Green Subsidies and Corporate Financial Performance

Government green subsidies play a critical role in mitigating the financial risks associated with environmental investment, particularly for firms facing high compliance costs. Such subsidies can alleviate financing constraints, encourage cleaner production practices, and improve both environmental and economic performance. Du et al. (2023) provide robust evidence that environmental protection subsidies significantly enhance firm performance in heavy-polluting industries, with green innovation serving as an important mediating mechanism. Complementary findings further indicate that subsidies mitigate the adverse financing effects of green credit policies and support firms' long-term investment decisions (Guo et al., 2023). These findings suggest that green subsidies function as an institutional incentive mechanism that helps align environmental objectives with corporate financial performance. Accordingly, this study proposes the following hypothesis:

H3: Green subsidies are positively associated with corporate financial performance in heavy-polluting industries.

2.5 Green Certification and Corporate Financial Performance

Green certification, such as ISO 14001, serves as a credible signal of a firm's environmental commitment and management quality. Signalling theory suggests that certified firms can reduce information asymmetry among investors, customers, and regulators, thereby improving market valuation and financial performance. Although certification-related evidence in heavy-polluting industries remains relatively limited, existing studies on environmental performance consistently indicate that formalised environmental management systems enhance corporate credibility and financial performance (Chen & Ong, 2022). Environmental certification may also complement green investment and green innovation by institutionalising environmental practices and strengthening governance effectiveness. Accordingly, this study proposes the following hypothesis:

H4: Green certification is positively associated with corporate financial performance in heavy-polluting industries.

3. Methodology

3.1 Data Sources and Processing

This study employs panel data from Chinese A-share listed companies on the Shanghai and Shenzhen Stock Exchanges covering the period from 2011 to 2023. The initial dataset was obtained from several authoritative sources, including the CSMAR Database, the Wind Database, and firms' annual reports. Following standard practices in empirical corporate finance and governance research, we applied several screening procedures to ensure data reliability and comparability. Heavy-polluting industries refer to industries that generate substantial amounts of harmful pollutants, such as sulphur dioxide, nitrogen oxides, particulate matter, and heavy metals, during production. These industries typically exert significant negative impacts on air, water, soil, and ecosystems and are subject to stricter environmental regulation and emission standards.

First, financial institutions were excluded because their financial structures, regulatory environments, and accounting practices differ substantially from those of non-financial firms (Fama & French, 1992; La Porta et al., 1997). Second, firms designated as *ST or ST were removed because these firms are subject to special regulatory treatment due to financial distress or abnormal business operations, which may distort the relationship between green initiatives and corporate financial performance. Third, observations with missing values for key variables were excluded from the sample. To mitigate the influence of extreme values, all continuous variables were winsorised at the 1% level at both tails. This procedure reduces the impact of outliers while preserving the overall distribution of the data and is widely adopted in firm-level panel data research (Petersen, 2009; Wooldridge, 2010). After applying these screening procedures, the final sample consisted of 912 firms from 15 heavy-polluting industries, including B06 Coal Mining and Washing, B07 Oil and Natural Gas Extraction, B08 Ferrous Metal Mining and Processing, B09 Non-ferrous Metal Mining and Processing, C17 Textiles, C19 Leather, Fur, Feather, and Footwear Manufacturing, C22 Paper and Paper Products Manufacturing, C25 Petroleum Processing, Coking, and Nuclear Fuel Processing, C26 Chemical Raw Materials and Chemical Products Manufacturing, C28 Chemical Fiber Manufacturing, C29 Rubber and Plastic Products Manufacturing, C30 Non-metallic Mineral Products Manufacturing, C31 Ferrous Metal Smelting and Rolling, C32 Non-ferrous Metal Smelting and Rolling, and D44 Electricity, Heat Production, and Supply. The final dataset comprised approximately 7,000 firm-year observations. Table 1 presents descriptive statistics for the main variables.

Table 1
Descriptive statistics

VarName	Obs	Mean	SD	Min	Median	Max
ROA	7000	0.0439	0.0483	-0.2234	0.0400	0.2331
GI	7000	0.1204	0.0709	0.0144	0.1080	0.5318
GIN	7000	0.1643	0.4733	0.0000	0.0000	2.8904
GS	7000	0.0311	0.0860	0.0000	0.0000	0.6682
GC	7000	0.3137	0.4640	0.0000	0.0000	1.0000
SIZE	7000	22.5078	1.3505	19.9977	22.2946	26.3886
CASH	7000	0.2569	0.3348	-0.4773	0.1862	1.8789
MBOARD	7000	2.1582	0.1977	1.6094	2.1972	2.7081
TOP	7000	0.3530	0.1487	0.0933	0.3291	0.7505
AGE	7000	2.2739	0.7792	0.6931	2.4849	3.3673
DUAL	7000	0.2361	0.4247	0.0000	0.0000	1.0000
LEV	7000	0.4385	0.1967	0.0636	0.4366	0.9643
GDP	7000	10.5876	0.7762	7.8095	10.6807	11.7715
CYJG	7000	2.4506	0.1267	2.2264	2.4363	2.8343

3.2 Variable Measurement

Dependent Variable

Corporate financial performance (CFP) is primarily measured using Return on Assets (ROA), calculated as net profit divided by average total assets. ROA is widely adopted in corporate finance and governance research as an indicator of firms' operational efficiency and profitability. To ensure the robustness of the empirical results, Return on Equity (ROE) and Tobin's Q are employed as alternative measures of corporate financial performance in additional robustness tests.

Independent Variables

This study examines four types of green initiatives:

- i) Green Investment (GI)
Green investment is measured as environmental protection expenditure divided by operating revenue. This indicator reflects firms' financial commitment to pollution control and environmental management activities.
- ii) Green Innovation (GIN)
Green innovation is measured by the annual number of green patent applications, reflecting firms' environmentally oriented technological innovation activities.
- iii) Green Subsidies (GS)
Green subsidies are measured as government environmental subsidies divided by operating revenue, representing the extent of policy support firms receive for environmental activities.
- iv) Green Certification (GC)
Green certification is measured using a dummy variable indicating whether a firm has obtained ISO 14001 environmental management system certification.

Control Variables

Following prior studies in corporate governance and sustainability research, several firm-level and regional control variables are included in the analysis:

- Firm Size (SIZE)
- Ownership Concentration (TOP)
- Leverage Ratio (LEV)
- Firm Age (AGE)
- Cash Holdings (CASH)
- CEO Duality (DUAL)
- Board Size (MBOARD)
- Regional GDP (GDP)
- Regional Industrial Upgrading Index (CYJG)

These variables control for firm characteristics, governance structures, and regional economic conditions that may influence corporate financial performance.

3.3 Operational Definition and Measurement of Variables

Table 2

Variable definitions and data sources

Variable Type	Variable Name	Operational Definitions	Data Sources
Independent Variable	Green Investment	Environmental Protection Expenditures / Operating Revenue	Wind, CSMAR Database, Corporate Annual Reports
Independent Variable	Green Innovation	Annual Green Patent Applications	National Intellectual Property Administration, Wind R&D Expenditure Data
Independent Variable	Green Subsidies	Green Subsidies / Operating Revenue	CSMAR Database, Listed Company Annual Reports
Independent Variable	Green Certification	ISO 14001 Certification Status	Wind Database, Certification Announcements, Corporate ESG Reports
Dependent Variable	ROA	Net Profit / Average Total Assets	CSMAR Database
Dependent Variable	ROE	Net Profit / Average Shareholders' Equity	CSMAR Database
Dependent Variable	Tobin's Q	Market Capitalisation / Capital Replacement Cost	Wind Database, CSMAR Database
Control Variable	Corporate Size (SIZE)	Expressed as the logarithm of the company's year-end total assets	Guotai An CSMAR Database, Wind Economic Database, and Listed Company Annual Financial Report Disclosure Data
Control Variable	Largest Shareholder Holding Ratio (TOP)	Calculated as the largest shareholder's stake divided by the company's total share capital	Guotai An CSMAR Database, Wind Economic Database, and Annual Financial Report Disclosure Data of Listed Companies
Control Variable	Debt-to-Asset Ratio (LEV)	Calculated as the company's year-end total liabilities divided by year-end total assets	Guotai An CSMAR Database, Wind Economic Database, and Annual Financial Report Disclosure Data of Listed Companies
Control Variable	Corporate Age (AGE)	Equal to the logarithm of the current year minus the company's founding year plus 1	Guotai An CSMAR Database, Wind Economic Database, and Annual Financial Report Disclosure Data of Listed Companies
Control Variable	Cash Holdings (CASH)	Net cash flow from operating activities divided by total assets	Guotai An CSMAR Database, Wind Economic Database, and Annual Financial Report Disclosure Data of Listed Companies
Control Variable	Regional GDP (GDP)	Refers to the final output of production activities by all resident units in the city over a specific period, encompassing the total value of goods and services	China Urban Statistical Yearbook and National Bureau of Statistics Public Macroeconomic Database
Control Variable	Dual Role Status (DUAL)	Set to 1 if the company's chairman and general manager are the same person; otherwise, set to 0	Guotai An CSMAR Database, Wind Economic Database, and Annual Financial Report Disclosure Data of Listed Companies
Control Variable	Regional Industry Upgrading (CYJG)	Regional tertiary industry value-added divided by secondary industry value-added	National Bureau of Statistics Regional Economic Database and Local Statistical Yearbooks
Control Variable	Board Size (MBOARD)	Measured by the number of board members	Guotai An CSMAR Database, Wind Economic Database, and Annual Financial Report Disclosure Data of Listed Companies

3.4 Model Settings

3.4.1 Baseline regression model

To examine the impact of green investment, green innovation, green subsidies, and green certification on return on assets, the following regression models are constructed:

$$ROA_{it} = \alpha_0 + \alpha_1 GI_{it} + \alpha_2 Control_{it} + \delta_i + \rho_t + \varepsilon_{it} \quad (1)$$

$$ROA_{it} = \beta_0 + \beta_1 GIN_{it} + \beta_2 Control_{it} + \delta_i + \rho_t + \varepsilon_{it} \quad (2)$$

$$ROA_{it} = \gamma_0 + \gamma_1 GS_{it} + \gamma_2 Control_{it} + \delta_i + \rho_t + \varepsilon_{it} \quad (3)$$

$$ROA_{it} = \theta_0 + \theta_1 GC_{it} + \theta_2 Control_{it} + \delta_i + \rho_t + \varepsilon_{it} \quad (4)$$

In the above equations, i denotes the firm and t denotes the year. The dependent variable is Return on Assets (ROA). The independent variables include green investment (GI), green innovation (GIN), green subsidies (GS), and green certification (GC), while Control represents the set of control variables included in the model. μ_i denotes the firm fixed effect, λ_t denotes the year fixed effect, and ε_{it} represents the random error term.

3.5 Robustness Checks

Several robustness tests are conducted to ensure the reliability and stability of the empirical findings. First, we estimate alternative model specifications by incorporating additional control variables and modifying the fixed-effects structure. Second, we exclude observations from the COVID-19 period to mitigate potential distortions caused by the pandemic shock. Third, alternative dependent variables, namely Return on Equity (ROE) and Tobin's Q, are employed to verify the robustness of the results across different measures of corporate financial performance. These robustness tests help confirm that the estimated relationships between green initiatives and corporate financial performance are not driven by model specification, sample selection, or variable measurement choices.

4. Results and Discussion

4.1 Benchmark Regression Results

4.1.1 Green investment

Table 3 presents the benchmark regression results for the effect of green investment on Return on Assets (ROA). Columns (1) and (2) report the regression results without and with control variables, respectively. The regression coefficients for the core explanatory variable are 0.0217 and 0.0273, both positive and statistically significant at the 10% and 5% levels, respectively. These findings suggest that green investment significantly enhances firms' ROA, regardless of whether the regression model includes control variables.

Table 3

Benchmark regression results - green investment

	(1)	(2)		(1)	(2)
	ROA	ROA		ROA	ROA
GI	0.0217*	0.0273**	LEV		-0.1176***
	(1.699)	(2.315)			(-23.807)
SIZE		0.0144***	GDP		0.0016
		(11.750)			(0.190)
CASH		0.0326***	CYJG		-0.0306
		(17.683)			(-1.312)
MBOARD		-0.0014	_cons	0.0657***	-0.1347
		(-0.314)		(10.876)	(-1.236)
TOP		0.0243***	FE	Yes	Yes
		(3.322)	Year	Yes	Yes
AGE		-0.0110***	N	7000	7000
		(-4.661)	R ²	0.4518	0.5543
DUAL		0.0014			
		(0.833)			

Note: t-statistics are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. The same notation is used in the subsequent regression tables.

4.1.2 Green innovation

Table 4 presents the benchmark regression results examining the effect of green innovation on Return on Assets (ROA). Columns (1) and (2) report the regression results without and with control variables, respectively. The regression coefficients for the core explanatory variable are 0.0056 and 0.0043, both of which are positive and statistically significant at the 1% level. These findings indicate that green innovation significantly improves firms' ROA regardless of whether control variables are included in the regression model.

Table 4

Benchmark regression results - green innovation

	(1)	(2)		(1)	(2)
	ROA	ROA		ROA	ROA
GIN	0.0056*** (3.862)	0.0043*** (3.223)	LEV		-0.1177*** (-23.835)
SIZE		0.0138*** (11.394)	GDP		0.0018 (0.211)
CASH		0.0324*** (17.597)	CYJG		-0.0314 (-1.344)
MBOARD		-0.0015 (-0.343)	_cons	0.0688*** (11.889)	-0.1175 (-1.081)
TOP		0.0245*** (3.354)	FE	Yes	Yes
AGE		-0.0107*** (-4.552)	Year	Yes	Yes
DUAL		0.0014 (0.879)	N	7000	7000
			R ²	0.4529	0.5546

4.1.3 Green subsidies

Table 5 presents the benchmark regression results examining the effect of green subsidies on Return on Assets (ROA). Columns (1) and (2) report the regression results without and with control variables, respectively. The regression coefficients for the core explanatory variable are 0.0155 and 0.0131, both positive and statistically significant at the 5% level. These findings indicate that green subsidies significantly improve firms' ROA regardless of whether control variables are included in the regression model.

4.1.4 Green certification

Table 6 presents the benchmark regression results examining the effect of green certification on Return on Assets (ROA). Columns (1) and (2) report the regression results without and with control variables, respectively. The regression coefficients for the core explanatory variable are 0.0033 and 0.0036, which are statistically significant at the 5% and 1% levels, respectively. These findings indicate that green certification significantly improves firms' ROA regardless of whether control variables are included in the regression model.

4.2.1 Alternative fixed-effects specification

To assess the sensitivity of the baseline results to the fixed-effects structure, this study re-estimates the four main models while retaining firm fixed effects and omitting year fixed effects. This alternative specification tests whether the estimated effects of green initiatives depend on including common year shocks, a standard concern in panel-data analysis (Wooldridge, 2010; Petersen, 2009). As reported in Columns (1)–(4) of Table 7, the coefficients for green investment, green innovation, green subsidies, and green certification are 0.0278, 0.0043, 0.0112, and 0.0026, respectively, and all remain statistically significant. The positive signs are consistent with the baseline regressions, indicating that the main relationships are not eliminated when year fixed effects are omitted.

Table 5

Benchmark regression results - green subsidies

	(1)	(2)		(1)	(2)
	ROA	ROA		ROA	ROA
GS	0.0155** (2.264)	0.0131** (2.112)	LEV		-0.1179*** (-23.880)
SIZE		0.0141*** (11.623)	GDP		0.0016 (0.190)
CASH		0.0324*** (17.564)	CYJG		-0.0302 (-1.293)
MBOARD		-0.0011 (-0.256)	_cons	0.0681*** (11.756)	-0.1255 (-1.154)
TOP		0.0239*** (3.270)	FE	Yes	Yes
AGE		-0.0110*** (-4.674)	Year	Yes	Yes
DUAL		0.0014 (0.858)	N	7000	7000
			R ²	0.4520	0.5542

Table 6
Benchmark regression results - green certification

	(1)	(2)
	ROA	ROA
GC	0.0033** (2.233)	0.0036*** (2.652)
SIZE		0.0139*** (11.490)
CASH		0.0325*** (17.631)
MBOARD		-0.0014 (-0.309)
TOP		0.0247*** (3.378)
AGE		-0.0113*** (-4.778)
DUAL		0.0014 (0.872)
LEV		-0.1175*** (-23.779)
GDP		0.0014 (0.161)
CYJG		-0.0338 (-1.448)
_cons	0.0678*** (11.683)	-0.1107 (-1.017)
FE	Yes	Yes
Year	Yes	Yes
N	7000	7000
R ²	0.4520	0.5544

4.2 Robustness Test

4.2.2 Eliminating the Impact of the COVID-19 Pandemic

To further address potential interference from exogenous shocks, this study excludes observations from 2020, during which the COVID-19 pandemic substantially disrupted corporate operations and financial performance (Ding et al., 2021). The regression models are then re-estimated using the remaining sample. The results reported in Columns (5)–(8) of Table 7 show that the coefficients for green investment, green innovation, green subsidies, and green certification remain positive and statistically significant after excluding 2020 observations. These findings suggest that the baseline results are not solely driven by the temporary shock associated with the COVID-19 pandemic.

Table 7
Robustness tests

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA	ROA
GI	0.0278** (2.498)				0.0257** (2.104)				-0.0231** (-2.002)			
GIN		0.0043*** (3.181)				0.0041*** (2.931)				0.0034*** (2.683)		
GS			0.0112* (1.798)				0.0108* (1.656)				0.0098* (1.656)	
GC				0.0026* (1.953)				0.0034** (2.401)				0.0035*** (2.747)
SIZE	0.0144*** (11.658)	0.0137*** (11.273)	0.0140*** (11.483)	0.0138*** (11.375)	0.0140*** (11.008)	0.0134*** (10.664)	0.0137*** (10.874)	0.0135*** (10.766)	0.0113*** (9.511)	0.0116*** (9.952)	0.0118*** (10.132)	0.0117*** (10.020)
CASH	0.0310*** (16.770)	0.0308*** (16.658)	0.0308*** (16.633)	0.0308*** (16.682)	0.0317*** (16.351)	0.0315*** (16.286)	0.0315*** (16.266)	0.0315*** (16.301)	0.0316*** (17.845)	0.0318*** (17.958)	0.0317*** (17.931)	0.0318*** (17.995)
MBOARD	-0.0000 (-0.008)	-0.0003 (-0.077)	0.0000 (0.006)	-0.0002 (-0.051)	-0.0016 (-0.334)	-0.0017 (-0.364)	-0.0013 (-0.289)	-0.0016 (-0.333)	-0.0014 (-0.327)	-0.0015 (-0.355)	-0.0012 (-0.285)	-0.0014 (-0.325)
TOP	0.0199*** (2.705)	0.0200*** (2.712)	0.0194*** (2.633)	0.0200*** (2.706)	0.0273*** (3.584)	0.0275*** (3.621)	0.0270*** (3.549)	0.0279*** (3.663)	0.0271*** (3.870)	0.0273*** (3.893)	0.0268*** (3.826)	0.0275*** (3.927)
AGE	-0.0146*** (-6.393)	-0.0145*** (-6.354)	-0.0148*** (-6.476)	-0.0150*** (-6.561)	-0.0114*** (-4.687)	-0.0111*** (-4.579)	-0.0114*** (-4.693)	-0.0117*** (-4.786)	-0.0085*** (-3.761)	-0.0084*** (-3.697)	-0.0086*** (-3.796)	-0.0089*** (-3.908)
DUAL	0.0012 (0.708)	0.0012 (0.743)	0.0012 (0.720)	0.0012 (0.727)	0.0003 (0.192)	0.0004 (0.214)	0.0004 (0.221)	0.0004 (0.226)	0.0006 (0.372)	0.0005 (0.343)	0.0005 (0.326)	0.0005 (0.335)
LEV	-0.1173*** (-23.832)	-0.1176*** (-23.925)	-0.1178*** (-23.962)	-0.1176*** (-23.912)	-0.1175*** (-22.793)	-0.1175*** (-22.802)	-0.1179*** (-22.873)	-0.1175*** (-22.787)	-0.1194*** (-25.153)	-0.1189*** (-25.062)	-0.1191*** (-25.101)	-0.1186*** (-25.002)
GDP	-0.0013 (-0.341)	-0.0026 (-0.684)	-0.0022 (-0.563)	-0.0023 (-0.593)	0.0007 (0.076)	0.0010 (0.116)	0.0006 (0.072)	0.0005 (0.055)	0.0042 (0.519)	0.0046 (0.559)	0.0044 (0.542)	0.0042 (0.517)
CYJG	-0.0190 (-1.096)	-0.0155 (-0.898)	-0.0145 (-0.843)	-0.0143 (-0.831)	-0.0189 (-0.790)	-0.0196 (-0.818)	-0.0183 (-0.764)	-0.0216 (-0.903)	-0.0131 (-0.582)	-0.0139 (-0.620)	-0.0129 (-0.577)	-0.0164 (-0.731)
GROWTH									0.0370*** (22.534)	0.0362*** (22.490)	0.0363*** (22.525)	0.0364*** (22.579)
_cons	-0.1529*** (-4.064)	-0.1299*** (-3.489)	-0.1427*** (-3.831)	-0.1384*** (-3.723)	-0.1444 (-1.277)	-0.1294 (-1.147)	-0.1349 (-1.196)	-0.1224 (-1.085)	-0.1454 (-1.389)	-0.1567 (-1.500)	-0.1629 (-1.558)	-0.1497 (-1.433)
FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	7000	7000	7000	7000	6345	6345	6345	6345	7000	7000	7000	7000
R ²	0.5414	0.5417	0.5412	0.5412	0.5586	0.5589	0.5584	0.5587	0.5887	0.5889	0.5886	0.5889

4.2.3 Adding additional control variables

To mitigate potential omitted-variable bias, we include firm growth (GROWTH) as an additional control variable. Firm growth is closely associated with profitability and investment behavior and may therefore influence corporate financial performance (McConnell & Servaes, 1995). As reported in Columns (9)–(12) of Table 7, green innovation, green subsidies, and green certification remain positive and statistically significant after firm growth (GROWTH) is added. In contrast, the coefficient of green investment becomes negative and statistically significant (-0.0231). This result indicates that the estimated effect of green investment is sensitive to the inclusion of firm growth; therefore, this specification provides mixed rather than uniform robustness evidence.

4.2.4 Alternative dependent variables

To address potential estimation bias from measuring corporate financial performance, this study conducts additional robustness tests by replacing the dependent variable. Although Return on Assets (ROA) is widely used as an accounting-based indicator of firm performance, it may be sensitive to accounting policies and short-term operational fluctuations. To ensure that a specific performance measure does not drive the baseline results, the regression models are re-estimated using Return on Equity (ROE) and Tobin's Q as alternative dependent variables. This approach is consistent with prior studies emphasising the importance of employing multiple performance indicators to validate empirical findings (Demsetz & Villalonga, 2001; Wintoki et al., 2012).

Table 8

Robustness tests using alternative dependent variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ROE	ROE	ROE	ROE	TobinQ	TobinQ	TobinQ	TobinQ
GI	0.1378*** (2.795)				0.8339*** (3.410)			
GIN		0.0061 (1.108)				0.0834*** (3.036)		
GS			0.0358 (1.385)				-0.0932 (-0.726)	
GC				0.0071				-0.0619**
SIZE	0.0317*** (6.179)	0.0291*** (5.743)	0.0297*** (5.859)	0.0293*** (5.774)	-0.4669*** (-18.332)	-0.4843*** (-19.268)	-0.4823*** (-19.161)	-0.4806*** (-19.125)
CASH	0.0402*** (5.213)	0.0393*** (5.091)	0.0391*** (5.073)	0.0394*** (5.108)	0.0927** (2.423)	0.0867** (2.268)	0.0875** (2.286)	0.0861** (2.251)
MBOARD	0.0141 (0.757)	0.0140 (0.749)	0.0148 (0.796)	0.0142 (0.761)	0.0409 (0.443)	0.0385 (0.417)	0.0394 (0.426)	0.0409 (0.442)
TOP	0.1187*** (3.884)	0.1189*** (3.890)	0.1176*** (3.847)	0.1194*** (3.906)	-0.1976 (-1.304)	-0.1934 (-1.276)	-0.1958 (-1.291)	-0.2058 (-1.358)
AGE	0.0099 (1.000)	0.0103 (1.039)	0.0098 (0.993)	0.0093 (0.943)	0.5281*** (10.783)	0.5331*** (10.879)	0.5285*** (10.782)	0.5333*** (10.873)
DUAL	0.0061 (0.883)	0.0064 (0.938)	0.0063 (0.924)	0.0064 (0.935)	-0.0949*** (-2.788)	-0.0926*** (-2.721)	-0.0924*** (-2.712)	-0.0924*** (-2.714)
LEV	-0.2659*** (-12.865)	-0.2672*** (-12.922)	-0.2676*** (-12.943)	-0.2667*** (-12.891)	0.0023 (0.023)	-0.0024 (-0.023)	-0.0074 (-0.072)	-0.0153 (-0.149)
GDP	0.0850** (2.394)	0.0847** (2.384)	0.0847** (2.383)	0.0841** (2.366)	0.0152 (0.086)	0.0169 (0.096)	0.0094 (0.054)	0.0122 (0.069)
CYJG	0.0153 (0.157)	0.0140 (0.143)	0.0164 (0.168)	0.0088 (0.090)	-0.1729 (-0.357)	-0.1881 (-0.388)	-0.1787 (-0.369)	-0.1206 (-0.249)
_cons	-1.4263*** (-3.129)	-1.3448*** (-2.954)	-1.3649*** (-2.997)	-1.3304*** (-2.921)	11.8095*** (5.224)	12.3187*** (5.459)	12.3366*** (5.461)	12.1450*** (5.378)
FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	7000	7000	7000	7000	7000	7000	7000	7000
R ²	0.2490	0.2481	0.2482	0.2482	0.6429	0.6427	0.6422	0.6425

(1) Using ROE as the Dependent Variable

ROE reflects firms' profitability from shareholders' perspective and captures how efficiently equity capital is utilised. Compared with ROA, ROE is more sensitive to firms' capital structure and financial leverage, both of which may influence the estimated relationship between green initiatives and corporate performance (Fama & French, 1998). As reported in Columns (1)–(4) of Table 8, the regression coefficients for green investment, green innovation, green

subsidies, and green certification are 0.1378, 0.0061, 0.0358, and 0.0071, respectively. Green investment is positive and statistically significant at the 1% level, whereas green innovation, green subsidies, and green certification are not statistically significant. These findings suggest that green investment has a more direct and immediate effect on shareholders' returns, possibly because of its tangible nature and relatively clear cost–benefit structure. By contrast, green innovation, green subsidies, and green certification may influence corporate performance through longer-term or indirect mechanisms that are less readily reflected in short-term equity returns. This interpretation is consistent with prior studies indicating that certain environmental initiatives primarily affect accounting-based performance measures rather than equity-based indicators in the short term (Clarkson et al., 2011).

(2) Using Tobin's Q as the Dependent Variable

To further examine whether green initiatives influence firms' market valuation, this study replaces the dependent variable with Tobin's Q, which captures investors' expectations regarding firms' future growth opportunities and intangible value. Tobin's Q is widely used in governance and sustainability research as a market-based indicator of long-term value creation (Lindenberg & Ross, 1981; Servaes & Tamayo, 2013). As shown in Columns (5)–(8) of Table 8, the regression coefficients for green investment, green innovation, green subsidies, and green certification are 0.8339, 0.0834, -0.0932 , and -0.0619 , respectively. Green investment and green innovation are positive and statistically significant at the 1% level. Green subsidies are not statistically significant, while green certification is negative and statistically significant at the 5% level. These findings suggest that capital markets positively value firms' green investment and innovation activities, which may signal stronger long-term growth potential and regulatory adaptability. The non-significant coefficient for green subsidies indicates that investors may regard subsidy support as temporary or policy-dependent. The negative coefficient for green certification suggests that certification may also be associated with compliance costs or implementation burdens that are reflected in market valuation. These heterogeneous results show that market-based performance measures do not respond uniformly to all forms of green initiatives.

(3) Summary of Robustness Results

Taken together, the alternative-dependent-variable tests provide mixed evidence across performance measures. Green investment is the most consistently positive dimension, remaining significant for both ROE and Tobin's Q. Green innovation is positive and significant for Tobin's Q but not for ROE; green subsidies are not significant for either alternative measure; and green certification is not significant for ROE and is negatively associated with Tobin's Q. The robustness analysis therefore supports a more nuanced conclusion: the financial effects of green initiatives vary with the performance indicator used.

5. Discussion

The baseline results provide evidence that corporate green initiatives are positively associated with financial performance in heavy-polluting industries. By focusing on green investment, green innovation, green subsidies, and green certification, the findings highlight the economic consequences of firms' environmental actions under conditions of stringent regulatory pressure and institutional oversight (Porter & van der Linde, 1995; Delmas & Toffel, 2008). The robustness tests, however, show that the strength and direction of these relationships vary across alternative specifications and performance measures, indicating that the effects should be interpreted with appropriate caution.

First, the positive relationship between green investment and corporate financial performance suggests that environmental expenditures in heavy-polluting industries should not be interpreted merely as compliance costs. Under strict environmental regulation, green investment may strengthen internal governance discipline by improving resource allocation efficiency and reducing exposure to regulatory penalties. This finding supports the argument that environmental investment can generate economic returns when embedded within a governance framework characterised by continuous monitoring and regulatory enforcement (Porter & van der Linde, 1995; Clarkson et al., 2011).

Second, the significant effect of green innovation underscores the importance of technological upgrading as a governance-consistent response to environmental regulation. In heavy-polluting industries, green innovation enables firms to comply with environmental standards while simultaneously improving productivity and operational efficiency. These findings are consistent with the innovation-offset hypothesis, which suggests that proactive technological responses to environmental regulation can mitigate compliance costs and enhance corporate performance (Porter & van der Linde, 1995; Zhang et al., 2019).

Third, the positive association between green subsidies and financial performance indicates that institutional incentives support corporate green transformation. Government subsidies may alleviate the financial constraints associated with environmental investment and innovation, particularly for firms operating in capital-intensive and highly regulated industries. Rather than directly generating performance gains, green subsidies appear to function as governance-supporting mechanisms that reduce the cost of regulatory compliance and enable firms to pursue environmentally responsible strategies without undermining short-term profitability (Li et al., 2017; Ren et al., 2021).

Fourth, green certification emerges as an effective external governance signal. Certification schemes such as ISO 14001 enhance transparency and credibility by signalling firms' compliance with environmental standards and commitment to responsible management practices. In heavy-polluting industries, where information asymmetry between firms and stakeholders is relatively pronounced, such signalling effects may strengthen stakeholder trust and reduce regulatory uncertainty, thereby contributing to improved financial outcomes (Delmas & Montes-Sancho, 2011; Bansal & Clelland, 2004).

Taken together, these findings suggest that green initiatives function as governance-related strategic responses rather than isolated environmental actions. In heavily regulated industries, firms that actively engage in green investment, innovation, subsidy utilisation, and environmental certification are better positioned to manage regulatory risks, strengthen organisational legitimacy, and achieve sustainable financial performance. The findings also help explain why the performance effects of green initiatives tend to be more pronounced in heavy-polluting industries than in less regulated sectors (Aguilera et al., 2007; He & Shen, 2019). The findings further help reconcile mixed evidence in the existing literature on the relationship between environmental responsibility and firm performance. Although green initiatives may impose short-term costs in loosely regulated environments, their governance value becomes more salient in contexts characterised by strong regulatory enforcement and institutional pressure. Under such conditions, environmental actions are closely linked to firms' governance quality and strategic adaptability, making their economic benefits more observable (Friede et al., 2015; Eccles et al., 2014). Overall, this study highlights the importance of institutional context in evaluating the financial consequences of corporate environmental strategies. The governance role of green initiatives appears particularly critical in heavy-polluting industries, where regulatory compliance, transparency, and accountability are central to firms' long-term performance and sustainability (Delmas & Toffel, 2008; He et al., 2020).

6. Conclusion

This study examines the impact of corporate green initiatives implemented under regulatory and institutional pressure on economic outcomes in heavily regulated industries. Using panel data from Chinese A-share listed firms in heavy-polluting industries from 2011 to 2023, this study analyses the effects of four types of green initiatives—green investment, green innovation, green subsidies, and green certification—on corporate financial performance. The baseline regression results support the four proposed hypotheses: green investment, green innovation, green subsidies, and green certification are positively associated with ROA. The robustness analysis shows, however, that these relationships are not equally stable across all specifications and alternative performance measures. Green investment is the most consistently positive dimension. In contrast, the effects of green innovation, green subsidies, and green certification vary across ROE and Tobin's Q. These findings indicate that the financial consequences of green initiatives depend partly on how corporate performance is measured. From a governance perspective, green initiatives enhance corporate performance through several interconnected mechanisms.

Environmental investment and green innovation improve operational efficiency and resource utilisation, thereby helping firms reduce environmental risks and strengthen their competitive capabilities. In addition, policy instruments such as green subsidies and environmental certification provide institutional support, reduce information asymmetry, and enhance stakeholder trust. Furthermore, structured environmental management practices strengthen corporate governance, improve transparency in environmental operations, and encourage a stronger long-term strategic orientation. Overall, the findings indicate that environmental responsibility and financial performance are not inherently contradictory in heavily regulated industries. When supported by effective institutional incentives and governance mechanisms, green initiatives can serve as pathways to both regulatory compliance and sustainable financial performance. Environmental strategies therefore function not only as environmental responses but also as governance tools that contribute to long-term corporate value creation.

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Declaration of Competing Interests

The authors declare no conflicts of interest.

CRediT Authorship Contribution Statement

Tian Yang: Conceptualisation; Methodology; Analysis; Writing - original draft

Teh Boon Heng: Analysis; Validation; Writing - review & revise

Kwan Jing Hui: Conceptualisation; Analysis; Supervision; Writing - review & revise

Availability of Data and Materials

The data used in this study were obtained from the CSMAR and Wind databases, which are licensed databases. Due to licensing restrictions, the underlying data cannot be made publicly available. Access may be obtained directly from the data providers subject to their licensing terms.

Ethics Declarations

This study did not involve human participants or animals. Ethical approval was therefore not required.

Generative Artificial Intelligence Declarations

The authors claim that artificially intelligent-assisted technologies, such as generative AI, were not used to generate content, ideas, or theories. We have just utilised AI to enhance readability and refine the language. This was used with extreme human control and oversight. The authors take full responsibility for reviewing and approving the content.

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