



Capital market oversight and internal capabilities: Synergistic drivers of corporate environmental performance in emerging economies

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ABSTRACT

This paper examines how financial market oversight interacts with firms' internal capabilities to shape environmental performance, using a large panel of Chinese listed companies from 2011 to 2021. We conceptualise investor attention, analyst coverage, and media scrutiny as financial governance mechanisms that complement internal production, management, and R&D capabilities. Drawing on resource-based and institutional perspectives, extended with dynamic capabilities and ESG finance theory, we develop a framework linking capability development to sustainability outcomes through capital market channels. Empirically, we construct a multi-dimensional environmental performance index verified against external signals and apply fixed-effects, dynamic panel estimators, and instrumental-variable strategies to address endogeneity and reverse causality. Results show that internal capabilities significantly improve environmental performance and that financial oversight amplifies these effects, reducing information asymmetry and strengthening market discipline. Interaction tests and event-study evidence around policy shocks confirm the synergistic mechanism. Our findings highlight the role of capital markets in promoting corporate sustainability in emerging economies, offering implications for investors, analysts, and policymakers seeking to integrate ESG considerations into valuation and governance practices.

1. Introduction

With the continued growth of the global economy, environmental pollution has become increasingly prominent, attracting attention from governments and the public (Zhang and Wu, 2023a). As the primary agents of economic activity and major producers of pollution, firms' environmental performance has emerged as a critical determinant of sustainable economic and social development (Chen et al., 2023; Fan and Yao, 2022; Opazo-Basáez et al., 2024). Although existing research has examined how to improve corporate environmental performance from the perspectives of either external market forces (Ioannou and Serafeim, 2015; Rehman et al., 2022)

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or internal capability building (Dzhengiz and Niesten, 2020; Maheswari, 2023), focusing solely on the impact of a single capability on environmental performance fails to capture the dynamic scenarios in which firms respond to market changes. Investigating the synergistic effects between these dimensions often aligns more closely with reality (Dzhengiz and Niesten, 2020). Stringent and stable market regulation can incentivise firms to strengthen their internal innovative capabilities, information capabilities, and relational capabilities (Wang et al., 2015), while robust organisational awareness and innovative capabilities enable firms to respond swiftly to market fluctuations (Li et al., 2019), thereby creating a virtuous cycle of "regulation-driven capability building and capability-facilitated compliance enhancement." Such synergistic effects generate significant efficiency gains, allowing firms to achieve breakthrough progress in environmental performance improvement. Although the importance of the synergistic perspective has been recognised, existing literature lacks an in-depth examination of which capabilities matter most for environmental performance under specific market contexts. Capital markets serve as a critical governance mechanism. This study selects investor attention, analyst coverage, and media visibility as its core proxy variables, with the following theoretical justifications. First, investor attention directly reflects the external monitoring and resource allocation functions of capital markets, compelling management to respond to environmental information and improve internal managerial capabilities to maintain market confidence (Hao and Xiong, 2021). Second, analyst coverage functions as a professional information intermediary; its continuous tracking constitutes an informal regulatory mechanism that incorporates environmental performance into evaluation systems, increases the potential reputational and financing costs associated with environmental oversight failures, and effectively constrains managerial opportunism (Zhang and Wu, 2023). Finally, media visibility acts as an amplifier of social opinion and legitimacy pressure, capable of rapidly influencing public and policy perceptions and exerting substantial informal regulatory pressure on firms (Chen et al., 2023). Investor attention represents market-based, decentralised capital forces; analyst coverage represents specialised, organised information forces; and media visibility represents social, opinion-based public forces. This combination enables a more comprehensive and dynamic capture of the complex role of capital markets as a governance mechanism, constituting an important theoretical innovation and measurement foundation for this study. Against this backdrop, this study aims to examine how firms' responses to diverse external market attention improve environmental performance through internal capability building. Drawing upon the theory of the firm, the research systematically integrates three internal capability elements: production capability, managerial capability, and R&D capability to reveal how their synergistic effects influence environmental performance. From the perspective of external market attention (Ordóñez-Borralló et al., 2024), we uncover the transmission mechanism through which internal capability building improves environmental performance. Meanwhile, we conduct grouped regressions based on firm pollution intensity, government policies, and other factors that may influence the driving effects to capture heterogeneous effects. The primary contributions of this study lie in internalising the external environment and systematically integrating the dual effects of internal capabilities and external market attention, thereby providing a theoretical foundation for firms to formulate environmental management strategies and offering new insights for policymakers to optimise corporate environmental regulatory mechanisms. Theoretically, this enriches the research framework for corporate environmental performance (Epstein et al., 2015). Simultaneously, by disaggregating external market attention into specific mechanisms, this approach provides a novel perspective on how to strengthen internal capabilities to enhance competitive advantage. Based on the conclusions of this paper, subsequent research may further explore the impact of other external factors on corporate environmental performance, thereby extending the boundaries of existing research. Against this background, this study pursues four closely related research objectives. First, it examines whether internal capability building, encompassing production, managerial, and R&D capabilities, directly enhances corporate environmental performance. Second, it investigates whether capital market oversight, in the form of investor attention, analyst coverage, and media monitoring, serves as a transmission mechanism through which internal capabilities translate into superior environmental outcomes. Third, it assesses whether different market-based monitoring channels play heterogeneous roles in this process, reflecting their distinct economic functions as resource allocators, information intermediaries, and legitimacy arbitrators. Fourth, it clarifies how the interaction between internal capabilities and external market governance shapes environmental performance in an emerging economy context characterised by institutional transition and ESG-oriented financial development. These objectives are directly reflected in the four hypotheses developed in Section 2 and allow us to articulate clear theoretical contributions to the resource-based view, institutional theory, and the literature on capital market governance and ESG performance. The remainder of this paper is organised as follows. Section 2 presents the literature review and hypotheses development. Section 3 elaborates on the research design, including the model framework, variable definitions, and data sources. Section 4 presents the empirical results. Section 5 discusses the findings. Sections 6 and 7 outline the theoretical contributions and managerial and policy implications, respectively. Section 8 concludes the paper, while Section 9 discusses limitations and future research directions.

2. Literature review and research hypotheses

Faced with mounting environmental pressures, firms have increasingly recognised that strengthening internal capabilities, particularly in production, management, and research and development (R&D), constitutes a critical means of enhancing environmental performance (Dzhengiz and Niesten, 2020). However, a research gap exists regarding the mediating role of external market attention (e.g., investors, analysts, and media) in the relationship between internal capability building and environmental performance (Ioannou and Serafeim, 2015; Rehman et al., 2022). Previous studies have often focused on single external forces, such as media or investor monitoring, while overlooking the synergistic effects among multiple market participants. This fragmented perspective fails to capture how these external stakeholders interact with firm capabilities to influence environmental outcomes.

2.1. Theoretical framework

Building upon the resource-based view, we extend this perspective in three directions. First, dynamic capabilities explain how firms transform resource endowments into superior environmental performance: sensing environmental risks and opportunities, seizing them through investment and process reengineering, and reconfiguring routines to embed green practices. Second, green intellectual capital encompassing human (skills and mindsets), structural (processes, certifications, data systems), and relational (trust with stakeholders) dimensions elucidates why capability investments are complementary and enduring (Chen, 2008). Third, digital transformation serves as an amplifying mechanism, enabling refined monitoring, disclosure, and data-driven eco-innovation; this channel also explains why market supervision plays a crucial role, as digital traces enhance observability and verifiability. Accordingly, we expect that internal capability building directly enhances environmental performance (H1), while investor attention, analyst attention, and media attention operate as distinct market-based transmission channels through which internal capabilities are translated into superior environmental outcomes (H2–H4). Rather than treating internal capabilities and external oversight as independent forces, this framework conceptualises them as complementary mechanisms: internal capabilities provide firms with the operational, managerial, and innovation-related capacity to improve environmental performance, while capital market oversight shapes the incentive structures, visibility conditions, and reputational consequences under which such capabilities are valued, disciplined, and translated into observable environmental outcomes.

2.2. Internal capability building and environmental performance

Corporate environmental performance has long constituted a significant aspect of firm investment, receiving considerable attention and close monitoring from stakeholders and investors, and is closely linked to firms' financial performance and credit standing (Dimitropoulos and Koronios, 2023). The key to improving environmental performance undoubtedly lies in monitoring firms' progress toward sustainable development goals (D'Adamo et al., 2021). Regarding internal capability building, firms' production capabilities, managerial capabilities, and R&D capabilities represent the primary focal points and critical elements of such construction. In terms of production capabilities, as early as 2001, King and Lenox demonstrated that lean production and environmental performance are complementary, as evidenced by a survey of nearly 10,000 U.S. manufacturing firms from 1991 to 1996. Recent literature also notes that for certain firms, proactive green transformation and upgrading or passive evasion of environmental governance can be regarded as their responses to environmental issues and regulations: either investing substantial funds in rectification (such as seeking low-energy-consumption, low-pollution production raw materials and equipment) or allowing environmental degradation at the expense of ecological integrity (Ren et al., 2024). Undoubtedly, the nature of production methods and the strength of firms' production capabilities exert significant influence on environmental performance improvement. Regarding managerial capabilities, the focus lies on regulations formulated by the corresponding leadership and top management. Research indicates that measures such as establishing green environmental awareness, promoting green behaviours, and forming comprehensive green human resource management systems can effectively influence environmental performance in both public and private enterprises (Al-Swidi et al., 2021; Tao et al., 2023). Employees and management, along with their organisational structures, can affect environmental performance (De Villiers et al., 2011). Findings from studies on hospitality companies demonstrate that top management's green commitment and intellectual capital have direct effects on environmental performance (Haldorai et al., 2022). In terms of R&D capabilities, Lee and Min (2015) concluded that green R&D investment is associated with firm performance, providing valuable insights into how firms can utilise resources and capabilities to comprehensively enhance performance. A recent study also indicates that proactive environmental strategies focused on developing environmentally friendly technologies can influence performance across various dimensions and enable firms to gain competitive advantages (Fousteris et al., 2018). Through R&D technological innovation, firms can improve their energy and environmental performance, rapidly seize market opportunities, and attract potential investors (Li et al., 2022; Cao et al., 2021). Based on the above discussion, this paper proposes the following hypothesis:

H1. : Internal capability building can significantly enhance environmental performance.

2.3. Mediating effects of external market attention

From an economic perspective, internal capabilities alone are not sufficient to guarantee superior environmental performance. While capabilities determine a firm's technical and organisational potential, external market oversight shapes the incentives and constraints under which such potential is deployed. Capital markets affect firms' environmental behaviour by influencing reputational costs, financing conditions, and managerial accountability. In this sense, internal capabilities reduce the marginal cost of environmental improvement, whereas market-based monitoring mechanisms increase the marginal benefits and expected penalties associated with environmental outcomes. The interaction between these forces provides a clear economic rationale for a mediation-based framework. The transformation of internal capabilities into superior environmental performance cannot be achieved without the identification, evaluation, and feedback from external markets. As key participants in capital markets, investors, analysts, and media constitute a multi-layered external governance and signal transmission network. We hypothesise that internal capability building enhances environmental performance more effectively by attracting and leveraging external market attention. Investors are the ultimate decision-makers in resource allocation. With the popularisation of ESG investment philosophies, investors have increasingly focused on firms' environmental risks and performance (Amel-Zadeh and Serafeim, 2017). Firms with strong internal capabilities actively disclose their environmental efforts to attract 'green capital,' while their sound environmental practices are more readily

recognised by investors, thereby obtaining higher valuations and lower financing costs (Cai et al., 2024; Dimson et al., 2015; Ming et al., 2023). This positive financial incentive and supervisory pressure from capital markets provide direct motivation for firms to continuously invest in environmental governance (Dyck et al., 2019). Therefore, investor attention plays a mediating role of "resource provision and incentive reinforcement" between internal capabilities and environmental performance. This hypothesis enriches micro-level evidence on the interaction between green finance and corporate environmental behaviour by demonstrating how investors "price" firms' environmental capabilities in capital markets and translate them into financial incentives. Analysts serve as professional information intermediaries and corporate monitors. Through in-depth research reports, they interpret and disseminate information regarding firms' environmental capabilities and performance, alleviating information asymmetry (Healy and Palepu, 2001). When firms' internal capability building proves effective, analysts are more likely to provide positive evaluations or incorporate them into ESG rating systems, thereby influencing the perceptions of numerous investors (Zhang and Wu, 2023b; Zhang, 2024). Conversely, analysts may also issue warnings regarding firms' environmental risks (Wang and Zhang, 2024). This professional "interpretation" and "amplification" effect increases the potential reputational costs of poor environmental performance and guides capital flows toward firms with superior environmental performance (Chatterji and Toffel, 2010; Flammer, 2015). Therefore, analyst attention serves a mediating role of "information decoding and reputation arbitration." This hypothesis highlights the unique value of information intermediaries in environmental governance, demonstrating their role in constraining and guiding corporate behaviour through market consensus, with important implications for refining disclosure-based environmental policies. The media represent a crucial force in shaping public agendas and social legitimacy (Shi et al., 2023). Based on agenda-setting theory and legitimacy theory, media coverage can significantly enhance the public visibility of corporate environmental issues; the greater the media attention firms receive, the higher their concern for external image and the more pronounced their emphasis on environmental performance issues (Chen et al., 2023b). Firms with strong internal capabilities are more likely to receive media acclaim for their positive environmental behaviours, thereby accumulating 'green reputation' capital; conversely, negative events resulting from capability deficiencies may trigger public opinion crises, effectively constraining corporate pollution behaviours (Aerts and Cormier, 2009; Tang and Tang, 2013; Guo and Lu, 2021). Media pressure not only influences consumer and public attitudes but may also trigger stricter government regulation or tie executive compensation to environmental performance, effectively incentivising firms to increase environmental investment and efforts (Kong et al., 2019). Therefore, media attention acts as a mediating role of "legitimacy granting and public pressure transmission." This hypothesis supports the supervisory function of media in environmental governance and extends the research boundary on how public opinion pressure drives firms to improve environmental performance. Based on the above discussion, this paper proposes the following hypotheses:

Economically, investor attention strengthens the payoff structure of environmental capability investments by lowering financing costs, improving capital allocation efficiency, and increasing managerial accountability, thereby transforming internal environmental efforts into tangible market rewards and stronger incentives for sustained environmental improvement (Gao and Connors, 2011). Accordingly:

H2. : Firms' internal capability building can improve their environmental performance by increasing investor attention.

From an economic standpoint, analysts reduce information asymmetry and coordinate market expectations, thereby amplifying the valuation and reputational effects of firms' environmental capabilities and increasing the disciplining role of capital markets. Accordingly:

H3. : Firms' internal capability building can improve their environmental performance by increasing analyst attention.

Economically, media attention operates less through continuous incentive alignment and more through discrete legitimacy shocks, suggesting that its mediating role may be contingent on event-driven dynamics rather than gradual capability accumulation. Accordingly:

H4. : Firms' internal capability building can improve their environmental performance by increasing media attention.

3. Research design

3.1. Model construction

To study the impact of internal capacity building on environmental performance, this paper sets up a baseline model as follows:

$$EnvP_{ij,k,t} = \alpha_{ij,k,t} + \beta_1 Internal_{ij,k,t} + \beta_2 Control_{ij,k,t} + Industry_i + Province_j + Firm_k + Year_t + \varepsilon_{ij,k,t} \quad (1)$$

Among them, subscripts i, j, k, and t represent industry, province, enterprise, and year, respectively. $EnvP_{ij,k,t}$ represents the environmental performance of a company; $Internal_{ij,k,t}$ represents the internal capacity building of the enterprise; $Control_{ij,k,t}$ is the set of control variables. $\varepsilon_{ij,k,t}$ is the residual term that follows a normal distribution. This article simultaneously controls for dummy variables of industry, province, firm, and year to absorb fixed effects as much as possible.

3.2. Empirical strategy and identification

Our baseline specification is a saturated fixed-effects panel model with firm, industry, province, and year FE, and clustered SEs at the firm level. To strengthen identification and mitigate reverse causality, we implement four layers of analysis: a) Dynamic panel

estimation using system GMM, treating EnvP as persistent and instrumenting lagged levels/differences internally. b) Lead-lag/placebo tests: we include future EnvP as a regressor and verify it does not predict current Internal (no pre-trends), whereas Internal predicts future EnvP. Regressing Internal on lead EnvP ($t + 1$) yields coefficients statistically indistinguishable from zero; conversely, Internal (t) predicts EnvP($t + 1$), supporting temporal ordering. c) Selection correction via entropy balancing (and PSM as robustness) on pre-treatment observables, followed by FE estimation on the weighted sample.

Instrumental-variables strategy for the main endogenous regressors:

- *Internal capabilities*: industry-year innovation policy exposure interacted with firm pre-sample R&D intensity; city-level S&T funding shocks; and long-run knowledge base instruments (e.g., historical patent stocks).
- *Analyst oversight*: exogenous coverage shocks from brokerage closures/mergers and index re-constitutions that add/drop firms.
- *Media oversight*: news-supply shocks (exogenous spikes in non-business news that crowd out firm coverage) and outlet-level policy changes.

We report Kleibergen–Paap, Cragg–Donald, and over-identification tests in the IV tables and show that results remain robust when using the original lagged-R&D IV only as a sensitivity check. Finally, we operationalise the “synergy” between internal and external forces through interaction terms (Internal $\times$ External) and verify mechanism consistency in event-study/DiD designs around environmental policy shocks (e.g., low-carbon city pilots), confirming that increased oversight strengthens the capability–EnvP link in treated locations/periods.

3.3. Variable Settings and Description

(i) Environmental Performance (EnvP)

Following the content analysis approach proposed by Sarfraz et al. (2020), Zhang et al. (2023), Li et al. (2023), and Clarkson et al. (2008), this study evaluates corporate environmental performance by quantifying and scoring text content disclosed in annual reports and corporate social responsibility reports. Drawing upon the methodology of Li et al. (2023), this paper divides the measurement dimensions of environmental performance into four levels: information disclosure, incentive and penalty mechanisms, public welfare organisations, and pollution prevention and control. Eight specific variables are used to describe corporate environmental performance through scoring (see Table 1).

We transform EnvP into a triangulated, multi-item continuous index through the following procedures: (i) Acquiring additional disclosure-based information: Beyond text disclosed by firms themselves, we incorporate disclosure-based elements adjusted from the commonly employed methodology of Clarkson et al. (2008); (ii) Integrating external signals: Independent verification is conducted for certain verifiable key claims. For instance, where available, ISO 14001 certification and clean production implementation are verified through external registries; (iii) Capturing adverse events: Negative information is proactively collected to balance self-promotion bias and identify potential “greenwashing” behaviours. For example, annual environmental administrative penalty records imposed on companies are systematically compiled from environmental protection department websites, regulatory announcements, and other channels, and incorporated as a negative indicator. Based on the comprehensive data obtained through the above methods, trained coders score each piece of information for each firm according to explicit guidelines, with Kappa coefficients calculated to ensure consistency. Each item is coded on an ordinal/continuous scale (non-binary), normalised to unify dimensions, and principal factor analysis is employed to determine the weights of each indicator. The weighted sum of the organised indicator values yields the comprehensive Environmental Performance Index (EnvP).

We report item definitions, coder guidelines, and inter-coder reliability (Krippendorff’s α). Two trained coders independently scored disclosure-based items. We report Krippendorff’s α for each item (range: 0.78–0.91); discrepancies were resolved by a third coder according to a pre-registered coding manual. Results remain robust when using Coder A only, Coder B only, or the intersection dataset. To detect greenwashing, we flag inconsistencies when positive disclosures coexist with penalties in a given firm-year; main conclusions hold after excluding inconsistent firm-year combinations. For robustness verification, we re-estimate models using (i) tax-based indicators (log of environmental tax intensity) and (ii) a pure penalty index, with results remaining unchanged. We flag firm-year combinations with positive disclosures but simultaneous penalties. After excluding flagged observations, coefficients for internal

Table 1
Selection of environmental performance indicators and assignment of variables.

DIMENSION	Variable Name	Variable assignment
Information disclosure	ISO Environmental Management System Certification	By scoring 1, others score 0
	Whether to disclose the social responsibility report	Disclosure score 1, other scores 0
Work rewards and punishments	Have you received environmental recognition?	Score 1 for occurrence, 0 for others
	Have you been subject to environmental penalties?	Score –1 for occurrence, 0 for others
Public welfare organisations	Environmental public welfare activities of enterprises	Score 1 for occurrence, 0 for others
Pollution prevention	The treatment of “three wastes” pollutants	Governance score 1, others score 0
	Implementation of Clean Production	If there is further quantitative information disclosure, 2 points will be awarded.
	Implementation status of energy conservation	Implementation score 1, other scores 0

Source: Adapted from Li et al. (2023) and Jinchang et al. (2023).

controls and supervision do not diminish but rather strengthen slightly.

(II) Internal Capability Building (Internal)

This paper focuses on quantifying and evaluating firms' internal capability building across three dimensions: production capability, managerial capability, and R&D capability. To avoid conflating production, management, and R&D capabilities, we treat them as distinct variables to prevent heterogeneity effects from being obscured. Production capability is measured by firm-level Total Factor Productivity (TFP, log-transformed), reflecting operational efficiency. Managerial capability emphasises efficiency and quality rather than mere expenditure levels; we measure this through Sales, General, and Administrative expense efficiency (SG&A/Sales, inverted and standardised), supplemented where feasible by internal control quality and audit stringency. This approach avoids presupposing that "administrative expenses are negative." R&D capability is measured by the logarithm of R&D investment, with R&D intensity serving as a robustness supplement. Subsequently, all indicators are first standardised to ensure identical scales. For negative indicators, the transformation method involves subtracting the standardised value from 1. Principal Component Analysis (PCA) is then employed to fit the three indicators into a unified internal capability index.

(III) External Market Attention

This paper examines the role of external markets primarily from the perspectives of investors, analysts, and media. Investor Attention: Records search volumes for keywords related to investor relations and intensity from the Baidu Index, using annual averages (as shown in the baseline model), with alternative measures based on shareholding proportions (e.g., institutional ownership ratio) employed in robustness tests. Analyst Monitoring: Counts the number of initial/covering reports by independent analysts and report frequency in the firm's annual reports, with weight adjustments for duplicate or jointly issued reports. Media Monitoring (Redefined): We construct a Media Monitoring Index (MOI) that integrates multiple indicators: (i) tone/sentiment (share of negative/critical ESG terminology), (ii) source credibility weighting (top-tier national media; investigative platforms), and (iii) event coverage (environmental-related investigations or regulatory news mentioning the firm). The MOI is standardised to mean 0 and standard deviation 1. Research demonstrates that simply counting article numbers underestimates media effects; in mediation effect tests, the MOI yields stronger and more interpretable coefficients.

(IV) Control Variables

In addition to core variables, this paper introduces firm-level and macroeconomic control variables. Specifically, these include: firm age (Lnage); economic development level (LnGDP); merger status; ownership concentration; audit opinion; industrial structure; and financial development level. Specific data sources and definitions are presented in Table 2.

3.4. Data description

This paper takes the listed companies of the Shanghai and Shenzhen stock exchanges from 2011 to 2021 as a sample. Enterprise

Table 2
Variable Sources and Descriptions.

Variable Type	Variable Name	Source	Definition
Explained variable	Environmental Performance	Shenzhen Stock Exchange	Comprehensive evaluation of corporate environmental performance based on relevant variables in the annual report, as detailed in 3.3. (I)
	production capacity	Shanghai Stock Exchange CSMAR	Following the approach of Levinsohn and Petrin (2003) , the LP method is used to estimate the total factor productivity of enterprises
Explanatory variable	management skills	CSMAR	Take the reciprocal of SG&A/sales revenue for standardisation, and add internal control quality and audit rigour as supplementary indicators when feasible
	R&D capability	CSMAR	R&D investment plus 1 takes the natural logarithm
	Investor focus	Baidu Index	Baidu searches for keywords related to investor relations and strength. And take the annual average.
	Analyst Focus	CSMAR	Count the number of independent analysts and the annual report frequency of the company, and adjust the weight of duplicate or jointly released reports.
	media attention	Shenzhen Stock Exchange Shanghai Stock Exchange CSMAR Chinese Research Data Services Platform	Build a media supervision index that integrates (i) tone/emotion (negative/critical ESG terms), (ii) source credibility weight (top national media; investigative platforms), and (iii) event reporting (involving environmental-related investigations or regulatory news mentioning the company). MOI is standardised to mean 0 and standard deviation 1.
Mediating variables	corporate age	CSMAR	Add 1 to the natural logarithm of the number of years from the establishment of the enterprise to the current year
	Economic development level	China Statistical Yearbook - National Bureau of Statistics	Take the natural logarithm of GDP
	Merge status	CSMAR	Merge= 1; Otherwise, merge= 0
	ownership concentration	CSMAR	Shareholding ratio of the top three shareholders
	audit opinion	CSMAR	Audit= 0 when the accounting firm issues a standard unqualified opinion; Otherwise, audit= 1
	industrial structure	China Statistical Yearbook - National Bureau of Statistics	The proportion of added value of the tertiary industry to GDP
	Financial development level	China Statistical Yearbook - National Bureau of Statistics	Proportion of total loans from regional financial institutions to GDP

data is mainly derived from the China Stock Market Accounting Research (CSMAR) database. The patent data is determined by matching the CSMAR database, the Chinese patent database, and the PC code of the International Patent Classification. The annual report data of enterprises comes from the official websites of the Shenzhen Stock Exchange and the Shanghai Stock Exchange; Region-level data are from the China City Statistical Yearbook. After excluding the samples with excessive information deficiency, this paper uses the regression imputation method to fill in the relevant data, and the final sample contains a total of 14608 observations from 1328 listed companies. The descriptive statistics of the variables are as follows:

As shown in Table 3, the mean of corporate environmental performance is 2.515 with a standard deviation of 2.364, indicating that the overall environmental performance of sample firms is at a moderate level, yet significant heterogeneity exists across firms, providing a necessary foundation for examining its driving factors. The distribution of internal capability building is relatively concentrated, while the three types of market monitoring mechanisms exhibit distinct characteristics: investor attention is generally high and uniformly distributed; media attention is at a medium-to-high level but varies considerably across firms; and analyst attention is relatively low overall with significant polarisation. Collectively, these data suggest systematic differences in the internal and external governance environments facing firms, offering a robust data foundation and empirical context for subsequent empirical testing.

4. Empirical results

4.1. Benchmark regression results

Table 4 presents the baseline regression results examining the impact of internal capability building on environmental performance improvement. Column (1) reports the fixed effects model estimates without control variables, controlling for firm, industry, province, and time fixed effects. Column (2) presents the estimation results after incorporating firm-level and macro-level control variables. The coefficient for the comprehensive internal capability index is 0.173, indicating that a one standard deviation increase in internal capabilities corresponds to approximately a 0.1 standard deviation improvement in corporate environmental performance, significant at the 1% level. Internal capability building exerts a significant positive effect on corporate environmental performance, thereby validating H1. The confirmation of this hypothesis substantiates the core tenet of the resource-based view: firm-specific, inimitable internal capabilities constitute foundational resources for building sustainable competitive advantages and achieving superior environmental performance. Corporate agency and resource endowments represent the fundamental internal drivers of green transformation.

4.2. Robustness test

To ensure the reliability of our findings, this paper conducts robustness tests. First, we employ an alternative measure of environmental performance. Following the measurement approach of Yu et al. (2020), we use the logarithm of "environmental tax as a proportion of operating revenue" to measure environmental performance (EnvPII), as shown in Column (3) of Table 4. Compared to scoring based on corporate annual reports, this metric objectively reflects the economic costs of firms' pollution emissions. The results demonstrate that internal capability building improves not merely what firms "disclose" but substantively what they "do." The coefficient for internal capability building is 0.356, significant at the 1% level, and larger than that in the baseline model. This suggests that OLS estimates may be biased due to measurement error, and that objective tax indicators more precisely capture the emission reduction effects generated by internal capability building, revealing greater environmental returns. Furthermore, to alleviate endogeneity bias potentially arising from bidirectional causality or common drivers between internal capabilities and contemporaneous control variables, we lag the control variables by one period. The test results are presented in Column (4) of Table 4. The coefficient for internal capability building is 0.184, significant at the 1% level. This further validates H1, indicating that the net effect of internal capability building remains robust after stripping away the interference of contemporaneous characteristics.

Table 3
Descriptive statistics.

VARIABLE	Obs	Mean	Std.Dev.	Min	Max
<i>EnvP</i>	14608	2.515	2.364	0	11
<i>Internal</i>	14608	-21.683	0.577	-2.536	1.061
<i>Investor</i>	14608	6.919	0.704	0	11.343
<i>Analyst</i>	14608	1.508	1.200	0	4.331
<i>Media</i>	14608	5.994	1.304	0	14.218
<i>Lnage</i>	14608	2.524	0.580	0.693	3.332
<i>Merger</i>	14608	0.222	0.416	0	1
<i>Concentration</i>	14608	46.782	15.866	15.823	87.241
<i>Audit</i>	14608	0.965	0.183	0	1
<i>Structure</i>	14608	53.228	13.394	0	83.870
<i>LnGDP</i>	14608	17.983	1.178	0	19.884
<i>Finance</i>	14608	1.589	0.696	0	7.450

Table 4
Benchmark regression results and robustness test.

VARIABLE	(1) EnvP	(2) EnvP	(3) EnvPII	(4) EnvP
<i>Internal</i>	0.168*** (0.044)	0.173*** (0.044)	0.356*** (0.052)	0.184*** (0.052)
<i>Lnage</i>		0.200 (0.126)	-0.138 (0.122)	0.088 (0.130)
<i>Merger</i>		-0.074 (0.054)	0.079 (0.057)	-0.002 (0.056)
<i>Concentration</i>		0.001 (0.003)	0.001 (0.003)	0.002 (0.003)
<i>Audit</i>		0.111 (0.089)	0.260*** (0.083)	0.238*** (0.092)
<i>Structure</i>		0.008 (0.007)	0.003 (0.007)	0.010 (0.007)
<i>LnGDP</i>		-0.005 (0.045)	0.037 (0.050)	-0.018 (0.043)
<i>Finance</i>		0.003 (0.072)	-0.010 (0.071)	0.016 (0.060)
Year/Province/Industry/Individual/Fixed Effect	Yes	Yes	Yes	Yes
sample size	14608	14608	14606	13279
Adj R-squared	0.667	0.668	0.556	0.677

Note: *, **, and *** indicate significance at 10%, 5%, and 1%, respectively, and the robust standard errors clustered to the enterprise level are in parentheses.

4.3. Endogeneity test I

This paper selects lagged R&D investment as the instrumental variable for internal capabilities. Firms' prior-period R&D investment represents critical historical investment in forming current technological and managerial capabilities, and past R&D investment cannot directly influence current environmental performance. Table 5 reports the instrumental variable regression results. The Kleibergen-Paap rk LM statistic is 301.62 ($p < 0.01$), rejecting the null hypothesis of "underidentification of instrumental variables." The Cragg-Donald Wald F statistic is 2431.26, substantially exceeding the Stock-Yogo critical value at the 10% level (16.38), strongly rejecting the null hypothesis of "weak instrumental variables." These results indicate that our instrumental variable selection is appropriate. After controlling for endogeneity, the coefficient for internal capability building is 0.443, remaining significant at the 1% level, thereby reaffirming H1. The IV estimate exceeds the baseline OLS estimate, suggesting that trade-offs between efficiency and environmental performance during internal capability enhancement exhibit fluctuations; when capturing the factor of R&D investment, the effect of internal capabilities on corporate environmental performance becomes more pronounced. This implies that OLS estimates may understate the true causal impact due to measurement error or omitted variable bias, and that the environmental returns to capability building are substantially larger once endogeneity is properly addressed.

4.4. Heterogeneity test II

(i) Heterogeneity Test Based on Firm Pollution Intensity

According to the Environmental Verification Industry Classification Management Catalogue for Listed Companies issued by the Ministry of Ecology and Environment, this paper classifies sample firms into heavy-polluting and non-heavy-polluting enterprises. Heterogeneity is identified through grouped regression tests, as shown in Columns (1) and (2) of Table 6. The coefficients for internal capabilities are positive and significant at the 5% level for both heavy-polluting and non-heavy-polluting enterprises, confirming the

Table 5
Endogeneity test.

	(1) Internal	(2) EnvP
Internal_iv	0.030*** (0.001)	
Internal		0.443*** (0.114)
control variable	Yes	Yes
Year/Province/Industry/Individual/Fixed Effect	Yes	Yes
Sample size	14608	
Kleibergen-Paap rk LM value	301.62***	
Cragg Donald Wald F-value	2431.26	
Stock Yogo Value	16.38	

Note: Same as Table 3.

Table 6
Heterogeneity test.

Variable	(1) Heavy polluting enterprises	(2) Non-heavy polluting enterprises	(3) Low-carbon pilot cities	(4) Non-low-carbon pilot cities
Internal	0.175 (0.086) **	0.130 (0.051) **	0.144**	0.172***
Control variable	Yes	Yes	Yes	Yes
Year/Province/Industry/Individual/ Fixed Effect	Yes	Yes	Yes	Yes
Sample Size	4515	10047	8520	6074
Adj R-squared	0.671	0.645	0.688	0.673

Note: Same as Table 3.

universality of H1. Notably, the coefficient for heavy-polluting enterprises is substantially larger than that for non-heavy-polluting enterprises. This disparity indicates a significant synergistic effect between external formal regulatory pressure and internal capability building. For heavy-polluting enterprises, greater legitimacy pressure renders the internal capabilities developed through corporate investment more urgently transformed into compliance achievements and environmental performance improvements, thereby generating higher marginal returns. Stringent external institutional pressure activates and amplifies the strategic value of internal resources, perfectly corroborating the mutual reinforcement between institutional theory and the resource-based view: external pressure and internal capabilities are not substitutive but rather complementary relationships.

(ii) Heterogeneity Test Based on Low-Carbon City Pilot Policy

To address climate change and achieve the "carbon peak and carbon neutrality" goals, the Chinese government launched the low-carbon city pilot policy in 2010. To date, three batches of pilot cities have been implemented. Based on the lists of these three batches, this paper divides the sample into low-carbon pilot cities and non-pilot cities according to the provinces and cities where firms are located, to examine whether government policies differentially affect the process of internal capability building and environmental performance. Columns (3) and (4) of Table 6 reveal that the coefficients for internal capability building are positive in both pilot and non-pilot cities, reaffirming the universality of H1. Notably, the coefficient for firms in non-pilot cities exceeds that for pilot cities. This result reveals a certain degree of "substitution effect" or "crowding-out effect" between external pressure and internal capabilities. In pilot cities, firms enhance environmental performance through government subsidies, technology promotion policies, and other support mechanisms, thereby diminishing the marginal utility of relying on differentiated competition through self-developed capabilities. Conversely, in non-pilot cities, where strong policy traction is absent, differences in corporate environmental performance depend more critically on the quality of self-directed capability building.

This finding enhances our understanding that synergy is not merely a linear strengthening relationship. Policy design should ensure that while providing incentives, firms are still encouraged to prioritise their own capabilities, avoiding excessive dependency on external support.

4.5. Mediation mechanism test

To examine whether internal capability building improves environmental performance by enhancing external market attention, this study employs the stepwise test method for mediation analysis. Columns (1) and (2) of Table 7 report that the coefficients of internal capabilities on investor attention and analyst attention are 0.031 and 0.242, respectively, both significant at the 1% level. Simultaneously, after controlling for internal capabilities, the coefficients of investor attention and analyst attention on corporate environmental performance are 0.157 and 0.120, respectively, both significant at the 1% level. These results validate H2 and H3. Furthermore, the coefficient of internal capabilities on analyst attention substantially exceeds that on investor attention, indicating

Table 7
Internal capacity building, external market attention, and corporate environmental performance.

Variable	(1) Investor	(2) Analyst	(3) Media	(4) EnvP	(5) EnvP	(6) EnvP
Internal	0.031*** (0.010)	0.242*** (0.026)	0.040 (0.024)			
Investor				0.157*** (0.046)		
Analyst					0.120*** (0.024)	
Media						0.086*** (0.026)
control variable	Yes	Yes	Yes	Yes	Yes	Yes
Year/Province/Industry/Individual/Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
sample size	14608	14608	14608	14608	14608	14608
Adj R-squared	0.793	0.641	0.695	0.668	0.669	0.668

Note: Same as Table 3.

that compared to investors, analysts, as professional information intermediaries, are more adept at identifying, interpreting, and disseminating corporate capability signals. Analyst attention constitutes a powerful external governance channel by reducing information asymmetry and influencing market reputation. Column (3) reveals that the coefficient of internal capabilities on media attention is not significant, leading to the rejection of H4. This finding suggests that corporate internal capability building represents a gradual process of capability accumulation, whereas media coverage is primarily driven by sudden events. This necessitates identifying a more stable indicator to reassess variations in media coverage. Nevertheless, Column (6) of Table 7 demonstrates that media attention exerts a positive effect on environmental performance, significant at the 1% level. This indicates that the media remains an effective supervisory force, although its mediating mechanism is limited. Taken together, the mediation results provide differentiated support for the proposed hypotheses. Hypotheses H2 and H3 are supported, indicating that investor and analyst attention constitute effective transmission mechanisms through which internal capabilities enhance environmental performance. In contrast, Hypothesis H4 receives only partial support. While raw media attention does not systematically mediate the capability performance relationship, additional analyses using the refined Media Oversight Index suggest that media monitoring may become relevant when measured through tone, source credibility, and event-based environmental scrutiny rather than through simple article counts. This asymmetry highlights the heterogeneous economic functions of different monitoring channels in emerging capital markets and suggests that media oversight is more event-driven and measurement-sensitive than investor and analyst attention.

4.6. Mediation and moderation

Using the refined measures, Internal significantly increases Investor and Analyst oversight; it also raises the Media Oversight Index, even when raw article counts show a weaker link. In the outcome stage, all three oversight channels are positively associated with EnvP. Formal mediation (seemingly unrelated regressions with bootstrapped indirect effects; KHB decomposition) indicates that Investor and Analyst channels mediate a sizable share of the Internal→EnvP effect; Media mediation becomes significant when using MOI (not mere counts). Moderation tests show Internal $\times$ External interactions are positive and significant, aligning with the “synergy” claim.

5. Discussion

Our findings are consistent with and extend prior research on capital market governance and ESG performance. While previous studies document that investor and analyst attention influence environmental disclosure and ESG ratings (Ioannou and Serafeim, 2015; Zhang and Wu, 2023), our results demonstrate that these mechanisms operate more deeply by mediating the transformation of internal capabilities into actual environmental outcomes. At the same time, the limited and measurement-sensitive mediating role of media attention aligns with studies emphasising its event-driven and legitimacy-oriented nature (Aerts and Cormier, 2009; Guo and Lu, 2021), rather than its capacity to sustain continuous incentive alignment. These findings therefore clarify why H2 and H3 receive stronger empirical support, while H4 depends more heavily on how media oversight is operationalised. Through empirical analysis of 1328 Chinese listed companies, this study reveals the mechanisms through which internal capability building and external market monitoring synergistically enhance corporate environmental performance. The findings indicate that: (i) firms' internal production, managerial, and R&D capabilities constitute the cornerstone of their environmental performance; (ii) investor attention and analyst attention serve as critical market bridges connecting internal capabilities and environmental performance, playing significant mediating roles; and (iii) the mediating effect of media attention is not substantiated, implying differential roles among various monitoring mechanisms in emerging markets. These developments confirm that environmental governance does not rely solely on

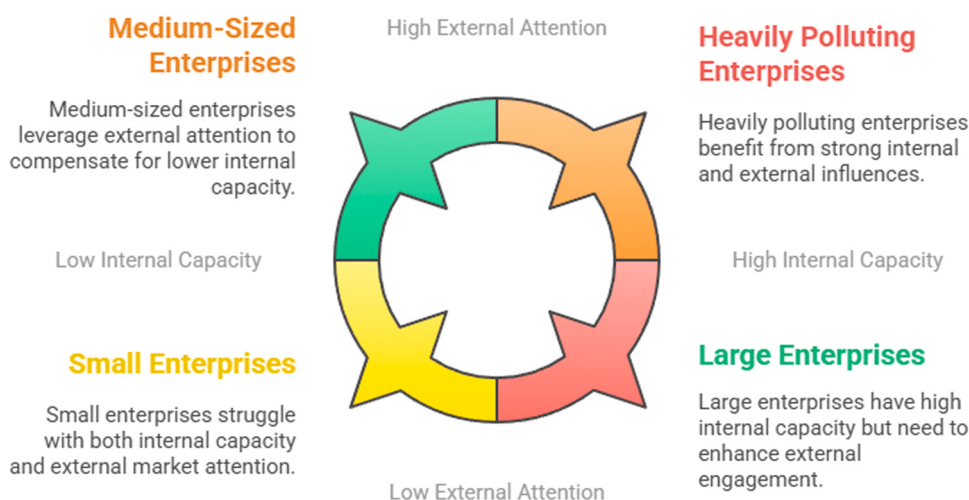


Fig. 1. Impact of internal and external factors on environmental performance.

government regulation or corporate self-discipline, but rather constitutes a complex system driven jointly by internal capability foundations and market monitoring networks. Accordingly, this paper discusses how different types of enterprises can leverage advantages in internal capabilities and external supervision and proposes corresponding strategic approaches.

Fig. 1 visually represents the interaction between internal capacity and external market attention concerning corporate environmental performance. It categorises enterprises into four groups based on their internal capabilities and external oversight:

(i) Heavily Polluting Enterprises (High Internal Capacity, High External Attention)

While such enterprises possess advantages in both dimensions, they also operate under intense pressure from external regulation and public opinion, where the cost of environmental missteps is extremely high. Accordingly, these enterprises should proactively set emission reduction targets exceeding regulatory requirements and make public commitments, systematically disclose advanced environmental management processes and technological innovations, and cultivate a professional, responsible leadership image. Simultaneously, they should leverage high attention levels to communicate long-term environmental strategies with investors and analysts, transforming environmental investments into ESG rating advantages and lower green financing costs.

(ii) Large Enterprises (High Internal Capacity, Low External Attention)**

Such enterprises possess solid internal capability foundations but remain undiscovered or undervalued by capital markets; their environmental performance may fail to receive deserved market returns. These enterprises should proactively disclose environmental indicators to attract market attention, establishing institutionalised, highly transparent environmental information dissemination channels. They should strengthen communication with ESG analysts and green investment institutions, guiding their attention toward the firm's less visible emission reduction efforts. Additionally, they should consider issuing green bonds and applying for sustainability-linked loans to capture investor group attention.

(iii) Medium-Sized Enterprises (Low Internal Capacity, High External Attention)

Such enterprises receive considerable external attention but lack sufficient internal governance capabilities, potentially facing reputational crises when unable to meet market expectations. Their primary task is to respond to external concerns while rapidly working to address capability deficiencies. Externally, they should candidly acknowledge their shortcomings and implement feasible short-term improvement plans; internally, they should explore capability gaps, strengthen collaborations with universities, research institutions, or environmental technology companies, and introduce external high-quality management models and advanced technologies to rapidly elevate technical and managerial standards.

(iv) Small Enterprises (Low Internal Capacity, Low External Attention)

Such enterprises lack both the motivation and the necessary resources for improvement. The key to enhancement lies in proactive engagement and strategic leverage of external opportunities. They should actively seek to utilise public policy resources, such as applying for government energy conservation and emission reduction subsidies and participating in environmental protection training programs. They should join industrial clusters or environmental alliances to collectively share pressures and costs. They should focus on select, high-priority improvement areas that yield both environmental and economic benefits, achieving breakthrough effects through targeted initiatives rather than attempting comprehensive coverage. Thus, Fig. 1 supports the core argument of this paper: dynamic interactions exist between internal capabilities and external supervision in shaping corporate environmental performance. This indicates that different enterprises should identify their unique positions within the Boston Matrix and adopt differentiated strategies to achieve systematic improvements in environmental performance.

6. Theoretical contributions

This study advances the sustainability and management literature in several ways. First, it bridges the resource-based view and institutional theory by demonstrating how the interplay between firms' internal capabilities and external oversight mechanisms jointly shapes environmental performance. This dual perspective enriches our understanding of sustainability drivers beyond a single theoretical lens (Ioannou and Serafeim, 2015; Kraus et al., 2020). Second, the study identifies a synergistic mechanism, showing that external stakeholders such as investors, analysts, and media not only exert pressure but also enhance the effectiveness of internal capability building. This contributes to the ongoing debate on the complementarity between internal resources and external governance (Chen, 2008; Dzhengiz and Niesten, 2020). Third, by focusing on Chinese listed firms, the research provides evidence from an emerging market context where regulatory, cultural, and institutional dynamics differ from those in developed economies, thus extending the generalizability of existing theories (Guo and Lu, 2021).

7. Managerial and policy implications

(i) Implications for Investors and Shareholders

Investors should incorporate firms' production, managerial, and R&D capabilities into their evaluation frameworks, serving as forward-looking signals for assessing long-term environmental risks and green competitiveness. They should proactively identify and invest in high-capability, low-attention firms, whose environmental value is currently underestimated. Through due diligence or interviews, they should verify these capabilities and position ahead of the market to capture excess green returns. When engaging with management, investors should move beyond inquiring about environmental targets to deeply probing the specific capability foundations supporting these targets, assessing whether the firm's groundwork is solid. Furthermore, shareholders should submit or support proposals for regular corporate disclosure of environmental indicators, providing concrete recommendations for improving capability disclosure and facilitating access to green technology resources, transforming passive monitoring into active empowerment.

(ii) Implications for Corporate Management

Management must understand that environmental performance should be transformed from a cost centre into a strategic core for value creation. The first step involves building solid internal capabilities: greening production processes, digitising management systems, and institutionalising green R&D, moving toward objectives of green processes, data transparency, and technological advancement (Basile et al., 2024). The second step requires proactive market communication: ESG reports should move beyond qualitative descriptions to provide quantitative evidence of key capabilities; establish targeted communication channels for analysts and investors, actively presenting the firm's true circumstances to garner support; and flexibly utilise green financial instruments to reduce financing costs while sending credible green signals to the market.

(iii) Implications for Policymakers

Policymakers should implement precise, differentiated policies for various firm types to stimulate endogenous motivation. They should link firms' economic benefits with environmental performance through fiscal subsidies, bonds, and other mechanisms, breaking the perceived trade-off between the two. For heavy-polluting enterprises, certification incentives should be tied to core capability enhancement, stimulating environmental motivation. Additional funding should be provided for firms' independent R&D or the introduction of internationally advanced emission reduction technologies, stimulating innovation vitality. Moreover, policymakers should establish corporate environmental information platforms, requiring firms to regularly upload data and providing free access for analysts, media, and the public. They should also invite experts to explain how to identify and evaluate corporate environmental capabilities, encouraging professional, in-depth market supervision.

(iv) Reflection on the Role of Media

Although the direct transmission pathway of media was not significant in this study, its role in agenda-setting and consensus-shaping remains irreplaceable. Media should engage in truthful, constructive reporting, reducing excessive sensationalism of environmental pollution incidents and pursuing a professional attitude of seeking truth from facts and speaking with data. They should strive to guide public attention toward firms' long-term green behaviours, resisting the current media landscape that prioritises sensationalism over substance. They should serve as communication bridges between firms and the public, inviting environmental experts and investors to engage in dialogue, translating complex technical language into market-comprehensible business and risk language, bridging information gaps, and facilitating the dissemination of valuable capability information in the market.

8. Conclusions

This paper empirically examines the synergistic effects of internal capability building and capital market monitoring on environmental performance improvement, using data from Chinese A-share listed companies from 2011 to 2021. The main conclusions are as follows:

(i) Firms' internal capabilities (production, management, and R&D) constitute a solid foundation for their environmental performance. Capability building not only directly promotes environmental performance, but its impact is more pronounced in heavy-polluting industries, indicating that stringent external regulation can amplify the environmental returns of internal capabilities.

(ii) Capital market monitoring exerts governance effects through differentiated mechanisms. Investor and analyst attention serve as critical mediating roles between internal capabilities and environmental performance, transforming corporate environmental efforts into market pressure and resource support through financing incentives and information decoding mechanisms, respectively. In contrast, the mediating role of media attention is not significantly supported, suggesting functional differences among various monitoring mechanisms in transitional markets.

(iii) Clear yet complex synergies exist between internal capabilities and external supervision. In environments with high regulatory pressure or high marketisation, the complementarity between the two is stronger; whereas in contexts with concentrated policy intervention, the marginal contribution of internal capabilities may be partially substituted. This indicates that formal regulation and informal market governance require dynamic coordination.

This study validates the interactive value of the resource-based view and institutional theory in the field of environmental governance, revealing that corporate green transformation is a systematic process driven jointly by endogenous capabilities and exogenous supervision. Future research may extend to more institutional contexts and explore the interaction mechanisms between emerging capabilities such as digital transformation and novel forms of supervision.

9. Limitations and future research

Despite its contributions, this study has several limitations that open avenues for future research. First, the empirical analysis relies on Chinese listed firms, which may limit the generalizability of the findings to other institutional and cultural contexts. Regulatory frameworks, market structures, and stakeholder pressures vary significantly across countries, and comparative studies could provide deeper insights into how institutional environments shape the interaction between internal capabilities and external oversight (Ioannou and Serafeim, 2015; Kraus et al., 2020). Second, while this study integrates production, management, and R&D capacities, it does not fully capture other organisational capabilities such as dynamic capabilities, green intellectual capital, or digital transformation that may also influence environmental outcomes (Chen, 2008; Dzhengiz and Niesten, 2020; Cao et al., 2021). Third, the role of external oversight was examined mainly through investors, analysts, and media, yet other stakeholders such as NGOs, customers, and government agencies may exert equally important or complementary effects (Guo and Lu, 2021; Rehman et al., 2022). Therefore, our evidence is drawn from Chinese listed firms and therefore reflects China's regulatory and media ecosystems; portability to other contexts where NGOs, courts, or local media differ in strength should be empirically verified. Measurement, while substantially enhanced, may still omit unobservable environmental outcomes not captured by penalties/certifications. Although we deploy multiple

identification strategies, residual endogeneity cannot be fully ruled out. Future research could (i) extend the framework cross-nationally; (ii) model non-market actors (NGOs, civic groups, environmental litigation) as additional oversight channels; (iii) trace micro-mechanisms with mixed-methods designs; and (iv) study the role of digital infrastructures (IoT, traceability systems) in strengthening capability-oversight complementarities. Furthermore, future research could broaden the scope of external actors and examine multi-stakeholder governance mechanisms. Finally, this study employs a quantitative approach, utilising secondary data, which, although rigorous, cannot fully reveal the underlying processes and managerial practices driving environmental improvements. Qualitative case studies, longitudinal designs, or mixed-method approaches would provide richer evidence of the causal mechanisms linking internal capacity building, external oversight, and corporate environmental performance (Epstein et al., 2015; Bhat et al., 2024).

CRedit authorship contribution statement

Xueyan Feng: Writing – review & editing, Writing – original draft, Conceptualization. **Shiqi Tao:** Writing – review & editing, Writing – original draft. **Yulong Wang:** Writing – review & editing, Writing – original draft. **Vincenzo Basile:** Writing – review & editing, Supervision, Software, Resources, Project administration, Formal analysis, Data curation. **Bhuiyan Miraj:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of Competing Interest

The authors declare that they have **no known competing financial interests or personal relationships** that could have appeared to influence the work reported in this paper.

The research was conducted **independently** and **received no external funding, sponsorship, or financial support** from any public or private organisation.

The authors confirm that **no commercial, institutional, or policy-related affiliations** influenced the study design, data collection, empirical strategy, analysis, interpretation of the results, or writing of the manuscript.

The dataset employed (CSMAR, Chinese patent database, China City Statistical Yearbook, and publicly available company disclosures) is **standard, publicly accessible, and not tied to any proprietary or sponsored programme**.

The authors further declare that they **have no financial, consultancy, or advisory relationships** with firms, analysts, investors, media groups, or capital-market institutions that could benefit from the findings of this research.

Accordingly, the authors state that **there are no conflicts of interest** to disclose.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.ribaf.2026.103519](https://doi.org/10.1016/j.ribaf.2026.103519).

Data availability

Data will be made available on request.

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