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Carbon Disclosure Quality, Internal Control, and Corporate Financial Performance

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Abstract

Amid intensifying climate commitments, this paper investigates whether and how carbon disclosure quality (CDQ) translates into corporate financial performance (CFP), and whether internal control (IC) strengthens this translation. Using a balanced panel of 1,218 Chinese A-share firms over 2010–2023, we build a multidimensional CDQ index – covering carbon governance, strategies and targets, footprints, and relevance/reliability – weighted via the entropy method and lagged to mitigate reverse causality. The sample comprises 15,834 firm-year observations, and models include firm, year, and industry fixed effects with clustered standard errors. Three-way fixed-effects estimations and two-step system GMM address unobserved heterogeneity and endogeneity; diagnostics (no AR (2), valid Hansen test) support instrument validity. Analyses further control for size, leverage, institutional ownership, board independence, ownership concentration, CEO duality, audit quality, heavy-polluting industry, and state ownership. The study finds that higher CDQ significantly improves CFP. Further, IC positively moderates the CDQ–CFP link: firms with stronger IC convert transparent carbon reporting into greater financial value, consistent with stakeholder theory. Results remain robust to an alternative market-based proxy (market-to-book ratio) and to exclusion of pandemic years (2020–2021), and are insensitive to multicollinearity checks. This study advances theory by demonstrating that credible climate disclosure yields financial benefits in an emerging market when coupled with effective internal governance; advances practice by highlighting that managers and regulators should pair disclosure mandates with IC reinforcement; and advances method by offering a replicable, Python-assisted scoring framework aligned with TCFD/ISSB guidance. Policy and investment implications follow: encouraging credible carbon reporting and strengthening internal control can lower information asymmetry, bolster legitimacy, and enhance firm valuation as economies transition to low carbon.

Keywords: carbon disclosure quality, corporate financial performance, internal control, stakeholder theory, fixed effects model, China

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Introduction

Corporate financial performance (*CFP*) refers to the financial value created by a firm and recognized by capital markets [1; 2]. While enhancing *CFP* is a core business objective, it is often achieved at the expense of environmental and social sustainability. Decades of profit-driven business activities have exacerbated climate change, threatening ecosystems and human well-being [3–6]. Prioritizing shareholder interests over those of stakeholders may jeopardize the legitimacy and long-term viability of a company [7; 8]. Empirical research shows that companies that integrate stakeholder engagement and sustainability into their operations tend to achieve better long-term market performance and financial results [9].

Given that companies are among the world's largest energy consumers and carbon emitters [4; 10], their emission reduction efforts directly reflect their commitment to creating a sustainable *CFP* creation [11–13]. As a core component of environmental governance, carbon disclosure provides stakeholders with forward-looking information on how companies measure, manage, and reduce their carbon footprint [14; 15]. The perceived quality of carbon disclosure, including completeness, accuracy, reliability, and timeliness, plays a critical role in influencing stakeholders' judgments and behaviors [16; 17]. High-quality carbon disclosure can build stakeholder trust, enhance corporate reputation, and support investors, regulators, and the public to make informed decisions [18].

With the growing global demand for sustainable *CFP* and climate action, China offers an attractive research environment for this study. As the world's second-largest economy and largest carbon emitter (about 30% of global emissions), corporate carbon disclosure in China is critical to achieving national sustainable development goals and global climate governance [19–22]. China's capital market has more than 5,400 listed companies and ranks second in the world in terms of market capitalization, providing a valuable research environment for exploring the impact of carbon disclosure quality (*CDQ*) on *CFP* [23; 24].

Despite the growing attention paid by academics and policymakers to the empirical relationship between *CDQ* and *CFP*, the conclusions are still unclear. While some studies report that high-quality carbon disclosure has a positive impact on *CFP* [25–27], other studies have found negative, insignificant, or even nonlinear associations between the two [2; 28; 29]. These mixed results suggest that the association may be context-dependent and shaped by firm-specific governance mechanisms, which influence how disclosure practices translate into financial outcomes.

Internal control (*IC*) is one such mechanism. Effective *IC* can ensure the integrity, consistency, and compliance of financial and non-financial information, thereby improving the reliability of carbon disclosure [30]. Effective *IC* can mitigate risks such as fraud and false reporting, while enhancing stakeholders' trust in the reliability of disclosed environmental information [31; 32]. However, despite the well-established role of *IC* in corporate governance and fi-

nancial reporting, few studies have explicitly explored how *IC* moderates the relationship between *CDQ* and *CFP* [33; 34]. To address these shortcomings, this study explores whether and how *CDQ* affects *CFP*, with a particular emphasis on the moderating role of *IC*.

This study has three main contributions. First, it expands stakeholder theory by empirically testing the link between *CDQ* and *CFP* in the context of emerging markets with significant climate responsibilities. Second, it enriches the governance literature by revealing the moderating effect of *IC* on the relationship between disclosure practices and financial outcomes. Third, from a methodological perspective, this study constructs a context-sensitive index for assessing the *CDQ* of Chinese listed companies, providing a more nuanced measurement framework that is consistent with local institutional conditions and reporting practices.

The remainder of the paper is structured as follows: second section reviews the relevant literature and proposes research hypotheses. Third section details the data, variable definitions, and empirical methods. Fourth section presents and discusses the empirical results. Finally, fifth section summarizes the main findings, highlights theoretical and practical implications, and outlines future research directions.

Literature Review and Research Hypotheses

Carbon Disclosure Quality and Corporate Financial Performance

With the growing global focus on climate change and decarbonization commitments, carbon disclosure has become a core component of corporate environmental governance and a key dimension in the broader Environmental, Social, and Governance (*ESG*) framework [35; 36]. According to stakeholder theory [7; 37], companies have to meet the information needs of not only shareholders, but also regulators, customers, employees, and the wider community. High-quality carbon disclosure is a reliable signal of a company's commitment to environmental sustainability and helps enhance stakeholder trust by improving transparency, accountability, and engagement [15; 16; 38]. In contrast, low-quality or superficial disclosures may cause stakeholders to be skeptical, undermine confidence, and may damage the legitimacy and long-term reputation of the company [25; 39].

Empirical studies on the relationship between *CDQ* and *CFP* have mixed results. Some studies have found evidence supporting a positive relationship. For example, Lu et al. [26] reported that carbon disclosure significantly increased the return on assets (*ROA*) of companies in non-carbon-intensive industries, and the positive effect persisted. Similarly, Cao et al. [25] found that *CDQ* was positively correlated with Tobin's *Q* (*TQ*), while Sun et al. [27] demonstrated that voluntary carbon emissions disclo-

sure helped to increase market capitalization (*MC*). However, other studies have shown that the financial benefits of carbon disclosure are not universal. For example, Asyifa and Burhany [40] found that carbon disclosure had no significant effect on *TQ*, and Siddique et al. [29] and Kurnia et al. [28] also reached the same conclusion.

Some studies even revealed negative or nonlinear effects. Siddique et al. [29] found that carbon disclosure was negatively correlated with *ROA*, while Zhu et al. [2] highlighted a U-shaped relationship between interactive carbon disclosure and *TQ*, indicating that information disclosure will only benefit *CFP* after exceeding a certain threshold. Similarly, Wang et al. [41] found that carbon disclosure may initially suppress *ROA* and subsequently make a positive contribution in the long run.

Taken together, the existing literature suggests that there are four broad empirical patterns between *CDQ* and *CFP* – positive, negative, zero, and nonlinear relationships. These inconsistencies can be attributed to differences in measurement methods, sample contexts, and time frames. Given the inconclusive evidence and the specific institutional and regulatory environment of China's capital market, further empirical research is necessary to elucidate how *CDQ* affects *CFP* of Chinese listed companies.

Based on stakeholder theory, transparent and credible disclosure practices can strengthen stakeholder relationships and legitimacy. This study proposes the following hypothesis:

H1: Carbon disclosure quality has a positive relationship with corporate financial performance.

Carbon Disclosure Quality, Internal Control, and Corporate Financial Performance

IC refers to the institutional mechanisms and processes established within a company. These mechanisms are implemented by the board of directors, management, and other corporate personnel [42]. Their primary aim is to protect the interests of various stakeholder groups. This is achieved by reducing opportunistic behavior, enhancing accountability, and improving transparency [7]. In the broader context of ESG and sustainability governance, effective *IC* can reasonably ensure that financial and non-financial reporting is accurate, timely, and consistent with regulatory requirements and stakeholder expectations [43; 44].

Effective *IC* is particularly important when it comes to complex and technical disclosures such as carbon-related information. Previous research shows that companies with effective *IC* are better able to ensure that climate-related disclosures are complete, verifiable, and consistent with international frameworks and market expectations [34; 45]. This not only enhances the credibility and comparability of disclosed data but also demonstrates the company's broader commitment to sustainable development goals [45]

As the cornerstone of corporate governance, *IC* has long been recognized as a key factor in determining a company's financial performance. On the one hand, effective *IC* can reduce the risk of financial misstatement, fraud, and operational inefficiency, thereby supporting profitability and enhancing investor confidence [46]. On the other hand, by promoting ethics, compliance, and transparency, *IC* helps build stakeholder trust and reinforces the legitimacy of corporate operations [47]. In addition, effective *IC* incorporates environmental indicators and sustainable development goals into operational oversight [30]. This helps ensure that corporate strategies are aligned with climate objectives. Therefore, *IC* is not only a safeguard for financial reporting, but also a governance infrastructure that enables companies to achieve sustained *CFP*.

Empirical research consistently supports the positive role that *IC* plays in driving *CFP*. For example, Cheng et al. [48] and Wang et al. [49] found that effective *IC* significantly improves total factor productivity (*TFP*), while Zhang and Su [44] showed that *IC* has a strong positive impact on both *ROA* and Return on Equity (*ROE*). In contrast, Baugh et al. [50] demonstrated that *IC* material weaknesses (*ICMW*) are associated with lower stock prices and lower *ROE*, highlighting the financial risks of weak governance systems.

In addition to its direct impact on *CFP*, *IC* can also amplify the financial benefits of corporate information disclosure. Yuan et al. [51] found that ESG disclosure is more effective in reducing financial irregularities when companies operate under stronger internal and external monitoring structures. Meng et al. [52] further demonstrated that *IC* can enhance the positive effect of environmental disclosure quality on easing financing constraints. In contrast, Boulhaga et al. [53] emphasized that the interaction term of *IC* weaknesses and ESG ratings has a negative and severe impact on *TQ*.

When applied to carbon emission disclosure, these insights point to the fact that a robust information disclosure system can enhance the reliability, consistency, and credibility of reported carbon information. This in turn can reduce stakeholder uncertainty, build trust, and transform high-quality information disclosure into tangible financial advantages, such as improved financing access and lower equity costs. According to stakeholder theory, firms with higher carbon disclosure quality are better positioned to leverage environmental transparency to achieve long-term improvements in *CFP*. While the relationship between *IC* and corporate value or disclosure has been extensively studied, its potential moderating role, particularly in the relationship between *CDQ* and *CFP*, has received relatively limited empirical attention. This gap is especially evident in studies related to China.

Given this theoretical foundation and empirical evidence, this study proposes the following hypothesis:

H2: Internal control positively moderates the relationship between carbon disclosure quality and corporate financial performance, such that the relationship is stronger when internal control is more effective.

Research Design

Sample Selection

This study employs a balanced panel dataset comprising Chinese A-share listed companies from 2010 to 2023. This study focuses on Chinese A-share listed companies – firms incorporated in mainland China, listed on the Shanghai or Shenzhen Stock Exchange, and traded in Renminbi (RMB) [24]. Two primary reasons underpin the selection of this time period. First, China committed to carbon emission reduction targets at the 2009 Copenhagen Summit and subsequently introduced a series of climate-related regulatory measures. Additionally, on 1 July 2009, the Basic Standards for Enterprise Internal Control began to be enforced for listed companies. Considering the lag in the actual implementation of these measures [30], 2010 is an appropriate starting point for empirical analysis. Second, 2023 was set as the endpoint to ensure the dataset remains up-to-date while fully covering the required variables over a meaningful period.

Only firms that consistently provided complete information on all key variables during the study period were included in the final sample, ensuring consistency and minimising biases caused by missing data. To enhance comparability and control for industry-specific effects, the sample excludes firms in the financial sector (due to their unique accounting standards and regulatory requirements) and companies designated as “special treatment” (ST) or “special transfer” (PT) due to financial distress or regulatory penalties.

After applying these criteria, the final balanced panel comprises 17,052 firm-year observations covering 1,218 A-share listed companies in China from 2010 to 2023.

Data and Variables

Data Source

The empirical analysis in this study is based entirely on secondary data. These data are obtained from reliable and well-established sources. This approach helps to enhance the robustness and credibility of the research findings. Specifically, financial information at the corporate level and key company attributes were extracted from the China Stock Market & Accounting Research (CSMAR) database. As one of the most authoritative financial databases in China, CSMAR has been widely used in peer-reviewed research and is widely recognised by researchers both domestically and internationally [25; 54].

The CDQ index was developed using content analysis. It is based on information disclosed in corporate annual reports, sustainability reports, corporate social responsibility (CSR) reports, and ESG reports. All of these reports are publicly available through Cninfo (<http://www.cninfo.com.cn/new/index>) [8; 30; 55]. Cninfo, as the official disclosure platform designated by the China Securities Regulatory Commission (CSRC), provides standardised and comprehensive documents for all listed companies. Additionally, IC data was extracted from the DIB database, maintained

by Shenzhen Dibo Risk Management Technology Co., Ltd. The DIB database is recognised as China's first specialised platform for storing corporate internal control information. It is widely used and frequently cited in empirical research on corporate governance [56].

Dependent Variable

In this study, CFP is defined as the financial value created by a firm and recognized by capital markets [1; 2]. To capture this market-oriented perspective, TQ is adopted as a proxy variable for CFP. TQ is calculated by dividing the firm's market value by its asset replacement cost and serves as an indicator of investor confidence and the firm's future expansion potential [57; 58]. In prior research in the ESG field, TQ has been used to assess firm value from a market-oriented perspective [53; 59]. To ensure the robustness of the research results, this study further introduces the market to book ratio (MB) as an alternative indicator [59; 60]. MB compares a company's market capitalization with its equity book value, providing an additional perspective on how the market assesses company value.

Independent Variable

In this study, the independent variable – CDQ – measures the extent of corporate carbon-related disclosure in terms of accuracy, completeness, timeliness, comparability, and verifiability [17; 25]. Given that Chinese companies have a relatively low level of participation in voluntary surveys such as CDP [61; 62], and China currently lacks a unified carbon disclosure standard and evaluation index system, resulting in variations in disclosure quality among companies and posing challenges for comparability and assessment [63]. The CDQ index is derived from a purpose-built structured assessment framework (Table 1), which aims to comprehensively evaluate the transparency and credibility of corporate carbon disclosure from multiple dimensions. It was constructed in accordance with the guidelines provided by TCFD, ISSB, GRI, MOF et al. [64], etc., as well as the results of previous studies [61; 63].

Specifically, the CDQ index comprises four core components: (A) Carbon Governance Mechanisms, (B) Carbon Strategies and Targets, (C) Carbon Footprints, and (D) Relevance and Reliability. Each dimension is operationalised through five detailed sub-indicators, resulting in a total of 20 scoring items, with a maximum score of 50 points. To ensure consistency and reproducibility, the data collection process utilised a custom-developed Python script that systematically extracted relevant corporate reports from Cninfo and parsed their content to support the scoring process. This method ensures that CDQ measurements remain objective and reproducible across different companies and reporting periods. While the text retrieval method ensures replicability, handling synonyms, negations, and context-specific meanings in carbon-related disclosures is a challenge. We recognize this limitation and suggest that future work could integrate advanced Natural Language Processing (NLP) techniques to improve the accuracy and depth of semantic interpretation.

Table 1. Carbon Disclosure Quality Evaluation Indicators and Criteria

First-Level Indicator	Second-Level Indicator	Evaluation Criteria
A. Carbon Governance Mechanisms	A1. Board supervision	1 point if the report discloses environmental protection concepts, environmental policies, circular economy initiatives, or green development strategies; 0 otherwise.
	A2. Management Responsibilities	1 point if the report identifies the regulatory body responsible for addressing climate change; 0 otherwise.
	A3. Employee Involvement	1 point if the report discloses mechanisms for encouraging employee participation in carbon reduction, such as environmental education or training; 1 additional point if the report describes participation in environmental campaigns, social welfare, or community activities; maximum 2 points; 0 otherwise.
	A4. Risk Management System	1 point if the report describes environmental management systems or related policies and procedures for identifying, assessing, and managing climate-related risks and opportunities; 0 otherwise.
	A5. Risks and Opportunities Identification	2 points if both climate-related risks and opportunities are disclosed; 1 point if only risks or opportunities are disclosed; 0 otherwise.
B. Carbon Strategies and Targets	B1. Low-Carbon Transition Strategy	1 point if a low-carbon transition strategy is disclosed; 0 otherwise.
	B2. Carbon Reduction Target	0 points if no target is disclosed; 2 points for qualitative targets; 4 points for quantitative targets.
	B3. Other Climate Management Goals	2 points if other climate-related goals are disclosed; 0 otherwise.
	B4. Emission Reduction Measures	0 points if no actions are disclosed; 2 points for qualitative information; 4 points for quantitative details on implementation.
	B5. Low-Carbon Business Transformation	0 points if no classification of products/services is disclosed; 2 points for qualitative information; 4 points for quantitative disclosure of low-carbon products/services.
C. Carbon Footprints	C1. Scope 1 Emissions	0 points if Scope 1 emissions are not disclosed; 2 points for qualitative disclosure; 4 points for quantitative disclosure.
	C2. Scope 2 Emissions	Same as C1.
	C3. Scope 3 Emissions	Same as C1.
	C4. Emission Intensity	0 points if carbon intensity indicators are not disclosed; 2 points for qualitative information; 4 points for quantitative disclosure.
	C5. Emission Changes	0 points if changes in total emissions (Scope 1 and 2) are not reported; 2 points for qualitative disclosure; 4 points for quantitative disclosure.
D. Relevance and Reliability	D1. Value Chain Engagement	1 point if the report discusses climate-related engagement with value chain partners, such as information exchange or joint initiatives with suppliers and customers; 0 otherwise.
	D2. Supply Chain Management	1 point if the report discloses climate-related requirements for suppliers or supply chain due diligence; 0 otherwise.
	D3. Other Climate Information	1 point if any additional climate-related indicators relevant to the company's operations are disclosed; 0 otherwise.
	D4. Disclosure Channels	1 point if disclosed in financial statements; 2 points if disclosed in a CSR or sustainability report; 4 points if disclosed in a stand-alone environmental or ESG report.
	D5. Disclosure Standards	1 point if the report follows an established reporting framework (e.g., GRI); 0 otherwise.

Source: TCFD, MOF et al. [64], ISSB, and CSMAR database.

When constructing composite indicators, it is crucial to ensure the reliability and validity of multi-indicator indices [65; 66]. To this end, a series of tests were conducted prior to index construction. The Kaiser-Meyer-Olkin (KMO) index score was 0.926, and the Bartlett sphericity test was statistically significant ($\chi^2(190) = 202.000$, $p < 0.001$), indicating that the sample was suitable for factor analysis and that there was sufficient correlation among the indicators [67; 68]. The Cronbach's alpha coefficients and composite reliability (CR) for each dimension exceeded the benchmark value of 0.70, confirming strong internal consistency [69]. The average variance extracted (AVE) for all constructs was above 0.50, providing evidence of convergent validity [70].

Considering the limitations of the equal-weight scheme [12] and the potential subjectivity of manual weight methods [8]. This study adopted the entropy weight method (EWM) to assign objective weights to the CDQ dimensions, which has been widely recognized and applied [71]. EWM was originally proposed by Shannon [72] in the context of information theory, determines the contribution of each dimension based on its information entropy, which reflects the degree of dispersion in the data. The CDQ index construction process is divided into three stages:

Stage 1: Standardization. To ensure comparability across companies and years, the raw scores for the four dimensions of CDQ were standardised using the minimum-maximum scaling method:

$$Z_{ijt} = \frac{D_{ijt} - D_{j,min,t}}{D_{j,max,t} - D_{j,min,t}}, \quad (1)$$

where D_{ijt} represents the raw score for firm i on dimension j in year t , while $D_{j,max,t}$ and $D_{j,min,t}$ represent the maximum and minimum scores for dimension j in year t . As all indicators are positively framed, no reverse coding was required.

Stage 2: Weight Derivation via Entropy. After standardisation, calculate the proportion of each company's score in each dimension relative to the total score:

$$p_{ijt} = \frac{Z_{ijt}}{\sum_{i=1}^n Z_{ijt}}, \quad (2)$$

where p_{ijt} represents the proportion of firm i 's score on dimension j in year t , and n is the total number of firms.

The entropy for each dimension was computed as:

$$e_j = -\frac{1}{\ln(N)} \sum_{i=1}^n \sum_{t=1}^T p_{ijt} \ln(p_{ijt}), \quad (3)$$

where T denotes the total number of years ($T = 14$), n denotes the number of firms ($n = 1,218$), thus, $N = n \cdot T$ represents the total number of firm-year observations in the entropy calculation. Since the entropy is derived from the pooled distribution of indicator values across all firms and years, the normalization constant $1/\ln(N)$ follows the standard Shannon-entropy formulation [72]. If $p_{ijt} = 0$, the term is defined as zero to maintain numerical stability.

The degree of information utility for each dimension was defined as $d_j = 1 - e_j$, and the standardised weights are calculated as:

$$w_j = \frac{1 - e_j}{\sum_{j=1}^4 (1 - e_j)}. \quad (4)$$

Ensure that the sum of all weights equals one.

Stage 3: Composite CDQ Index Calculation. Finally, the CDQ index for each firm-year was derived by aggregating the standardised dimension scores according to their respective entropy weights:

$$CDQ_{it} = \sum_{j=1}^4 w_j Z_{ijt}. \quad (5)$$

Higher values of CDQ_{it} (bounded between 0 and 1) indicate superior carbon disclosure quality. To mitigate the issue of reverse causality, the CDQ variable is lagged by one year when included in the regression model [61].

Moderating Variable and Control Variables

In this study, *IC* serves as a moderating variable. *IC* is defined as the processes established by an organisation's board of directors, management, and relevant employees to provide reasonable assurance for achieving operational, reporting, and compliance objectives [42]. Following previous empirical studies [49; 56; 73], the *IC* index was obtained from the *DIB* database and standardised by dividing its original value by 100. A higher standardised value indicates more effective *IC*. To mitigate endogeneity and temporal reverse causality, the *IC* index is lagged by one period [49].

To account for firm-specific heterogeneity and align with existing literature, several firm-level control variables were included in both regression models.

Firm Size (*Size*), measured as the natural logarithm of total assets, controls for the resource availability and scale effects that may influence both disclosure practices and financial performance [2; 74; 75].

Leverage (*LEV*), defined as the ratio of total liabilities to total assets, captures financial risk and debt pressure, which can affect both the incentive and ability to engage in carbon disclosure [41; 54; 76].

Institutional Investor Ownership (*IIO*), expressed as the proportion of shares held by institutional investors, reflects external monitoring intensity, which may shape governance practices and disclosure quality [77; 78].

Independent Director Ratio (*IDR*), the proportion of independent directors on the board, serves as a proxy for board independence and its capacity to ensure transparency [54; 79].

Ownership Concentration (*Top1*), measured by the largest shareholder's ownership proportion, accounts for the influence of dominant shareholders on strategic decisions, including disclosure policies [79; 80].

Table 2. Definition of Variables

Variable Type	Variable	Source	Variable Description
Dependent Variables	Corporate Financial Performance (CFP)	CSMAR	(Market Value of Equity + Liabilities)/ Total Asset
Independent Variable	Carbon Disclosure Quality (CDQ)	Cninfo	Calculated from Equation (5)
Moderator Variable	Internal Control (IC)	DIB	IC Index/100
Control Variables	Firm Size (Size)	CSMAR	Natural Logarithm of Total Assets
	Leverage (LEV)	CSMAR	Total Liabilities Divided by Total Assets
	Institutional Investor Ownership (IIO)	CSMAR	The Proportion of Shares Held by Institutional Investors
	Independent Director Ratio (IDR)	CSMAR	The Proportion of Independent Directors on the Board
	Ownership Concentration (Top1)	CSMAR	The Largest Shareholder's Ownership Proportion
	CEO Duality (Dual)	CSMAR	1 if the CEO Also Serves as Board Chair and 0 otherwise
	Audit Quality (Big4)	CSMAR	1 if the Firm has Hired Any of the Big Four Accounting Firms, and 0 otherwise
	Heavily Polluting Industry (Heavy)	CSMAR	1 if the Firm Operates in an Industry Classified as Heavily Polluting, and 0 otherwise
	State-Owned Enterprises (SOEs)	CSMAR	1 if the Firm is a State-Owned Enterprise, 0 otherwise

Note: All continuous variables are winsorized at the 1st and 99th percentiles.

Source: Own research.

Additionally, several governance and environmental factors are controlled for using dummy variables:

CEO Duality (*Dual*) equals 1 if the CEO also serves as board chair and 0 otherwise, capturing potential agency risks and weakened oversight [79; 81; 82].

Audit Quality (*Big4*) equals 1 if the firm engages one of the Big Four audit firms, indicating higher external assurance and disclosure credibility (Deloitte, PwC, EY, or KPMG), and 0 otherwise [4; 8].

Heavily Polluting Industry (*Heavy*) equals 1 for firms operating in environmentally sensitive industries, controlling for differential regulatory pressure and disclosure requirements [83; 84].

State-Owned Enterprises (*SOEs*) equals 1 for state-owned enterprises, as ownership structure may affect both compli-

ance incentives and stakeholder expectations [79; 82; 84].

To reduce the impact of outliers, all continuous variables are winsorized at the 1st and 99th percentiles [60; 85]. Detailed definitions and measurement methods for each variable are summarised in Table 2.

Methodology

Although some studies have suggested potential nonlinear relationships between ESG disclosure and corporate performance, we empirically examined this possibility by incorporating a quadratic term of CDQ into the baseline model. The estimation results show that the coefficient of the squared term is positive but statistically insignificant ($p = 0.155$), indicating that there is no strong evidence supporting a nonlinear specification in our context.

This study employs a linear panel regression model to ensure theoretical clarity and empirical robustness [1; 86; 87]. Linear models allow the estimation of average marginal effects and are widely used in related studies [88]. To ensure the applicability of the selected estimation strategy, a series of specification tests were conducted. Specifically, the F-test was used to compare the fixed effects (FE) model with pooled ordinary least squares (OLS); the Breusch – Pagan Lagrange multiplier (LM) test was employed to contrast the random effects (RE) model with pooled OLS; and the Hausman test was conducted to determine whether the FE or RE specification was more suitable for the data structure. The test results consistently supported the use of the FE specification for this panel dataset.

Therefore, all regressions were estimated using FE effects to control for unobservable time-invariant heterogeneity across firms. Additionally, year and industry FE were included to account for macroeconomic shocks and industry-specific dynamics over time. To address potential heteroskedasticity and serial correlation within firms, robust standard errors were clustered at the firm level [89; 90].

Model design

To test the direct impact of CDQ on CFP and examine whether IC moderates this relationship, two panel regression models are used. The baseline model (Model 1) tests the main effect (H1), while the moderation model (Model 2) tests the interaction effect (H2):

$$CFP_{it} = \alpha_0 + \beta_1 CDQ_{i,t-1} + \gamma' Control_{it} + \mu_i + \lambda_t + \kappa_s + \varepsilon_{it}; \quad (\text{Model 1})$$

$$CFP_{it} = \alpha_0 + \beta_1 CDQ_{i,t-1} + \beta_2 IC_{i,t-1} + \beta_3 (CDQ_{i,t-1} \cdot IC_{i,t-1}) + \gamma' Control_{it} + \mu_i + \lambda_t + \kappa_s + \varepsilon_{it}, \quad (\text{Model 2})$$

where CFP_{it} represents the financial performance of firm i in year t . $CDQ_{i,t-1}$ is the lagged carbon disclosure quality index. $IC_{i,t-1}$ represents the lagged internal control index. $CDQ_{i,t-1} \cdot IC_{i,t-1}$ is the interaction term capturing the conditional effect of CDQ depending on the strength of IC. $Control_{it}$ is a vector of firm-specific control variables, in-

cluding firm size, leverage, institutional ownership, board independence, and other relevant firm characteristics. μ_i captures firm FE to control for time-invariant unobserved heterogeneity; λ_t accounts for year FE to absorb macroeconomic and regulatory shocks; and κ_s controls for industry FE. ε_{it} is the idiosyncratic error term.

Table 3. Summary Statistics of Key Variables

Variable	Obs	Mean	SD	Min	Max
CFP	17.052	1.844	1.085	0.810	6.895
CDQ	17.052	0.257	0.211	0	0.965
IC	17.052	6.629	0.844	2.731	8.737
Size	17.052	9.852	0.589	8.796	11.532
LEV	17.052	0.453	0.198	0.057	0.856
IIO	17.052	48.783	22.651	0.671	91.073
IDR	17.052	37.366	5.501	33.33	57.14
Top1	17.052	34.575	15.291	7.949	74.870
Dual	17.052	0.203	0.402	0	1
Big4	17.052	0.085	0.279	0	1
Heavy	17.052	0.324	0.468	0	1
SOEs	17.052	0.533	0.499	0	1

Note: Corporate Financial Performance (CFP), Carbon Disclosure Quality (CDQ), Internal Control (IC), Firm Size (Size), Leverage (LEV), Institutional Investor Ownership (IIO), Independent Director Ratio (IDR), Ownership Concentration (Top1), CEO Duality (Dual), Audit Quality (Big4), Heavily Polluting Industry (Heavy), State-Owned Enterprises (SOEs).

Source: Own elaboration.

Empirical Results and Discussion

Descriptive Statistics

Table 3 presents the descriptive statistics for all key variables in the empirical analysis. The mean value of *CFP* is 1.844, with a standard deviation of 1.085, indicating moderate variation in financial performance across firms in the sample. The mean score for *CDQ* is 0.257, suggesting that overall carbon disclosure quality is low but varies across firms, consistent with previous findings from voluntary disclosure studies in China [61]. The average value of the *IC* index is 6.629, with a minimum value of 2.731 and a maximum value of 8.737, highlighting significant differences in governance quality among firms.

The average value of *Size* is 9.852, with a standard deviation (*SD*) of 0.589, indicating that most firms in the sample are medium-to-large listed companies. The mean *LEV* was approximately 0.453, indicating that firms on average financed approximately half of their total assets through debt. There were significant differences in the *IIO*, with an average of 48.783% and a range from less than 1% to over 90%, indicating varying degrees of institutional oversight. Board characteristics show that the *IDR* is 37.366%, which meets the governance requirements of China's capital market. The mean *Top1* is 34.575%, indicating that the largest shareholder typically holds a significant but non-majority stake. Regarding *Dual*, approximately 20% of firms exhibit CEO duality (*Dual* = 0.203), 8.5% are audited by the *Big4*, 32.4% operate in *Heavy*, and over half are state-owned enterprises (*SOEs* = 0.533).

Overall, the results of the descriptive analysis confirm that the main explanatory variables and control variables exhibit sufficient variability across both cross-sectional and

time dimensions, providing validity support for further multivariate analysis.

Correlation Analysis

Table 4 presents the Pearson correlation coefficients between the main variables in this study. Several notable patterns emerge. First, the correlation between *CDQ* and *CFP* is negative and significant at the 1% significance level ($r = -0.180$). This suggests that companies with higher *CDQ* may initially exhibit lower *CFP* in bivariate analysis. However, this simple correlation does not account for firm-specific heterogeneity and other control factors. As shown in the subsequent regression results, once firm characteristics and *FE* are considered, the relationship between *CDQ* and *CFP* significantly shifts to a positive correlation, indicating that higher-quality carbon disclosure can enhance financial outcomes after controlling for relevant factors. Meanwhile, there is a weak and statistically insignificant correlation between *IC* and *CFP* ($r = -0.012$), indicating no clear linear association at the bivariate level.

Regarding governance characteristics, the *IDR* is positively correlated with *CFP* at the 10% significance level ($r = 0.015$), indicating a moderate association. Moreover, *Dual* is significantly positively correlated with *CFP* ($r = 0.081^{***}$), which may reflect the mixed impact of leadership structure on the performance of sample companies. In contrast, most other control variables exhibit negative and significant bivariate correlations with *CFP*. For example, *Size* and *LEV* are both negatively correlated with *CFP* ($r = -0.419^{***}$ and $r = -0.347^{***}$), indicating that larger companies with higher leverage ratios tend to exhibit lower raw financial performance when other factors are not controlled. *IIO*, *Top1*, *Big4*, *Heavy*, and *SOEs* also exhibit similar patterns.

Table 4. Pearson Correlation Matrix of Key Variables

Variable	CFP	CDQ	IC	Size	LEV	IIO
CFP	1					
CDQ	-0.180***	1				
IC	-0.012	0.060***	1			
Size	-0.419***	0.522***	0.207***	1		
LEV	-0.347***	0.176***	0.036***	0.516***	1	
IIO	-0.050***	0.216***	0.220***	0.447***	0.214***	1
IDR	0.015*	0.052***	0.011	0.081***	0.033***	-0.013*
Top1	-0.090***	0.061***	0.155***	0.211***	0.099***	0.608***
Dual	0.081***	-0.083***	-0.046***	-0.144***	-0.117***	-0.225***
Big4	-0.109***	0.220***	0.149***	0.359***	0.118***	0.254***
Heavy	-0.022**	0.167***	-0.020***	0.039***	-0.054***	0.040***
SOEs	-0.164***	0.175***	0.100***	0.316***	0.263***	0.432***

Variable	IDR	Top1	Dual	Big4	Heavy	SOEs
IDR	1					
Top1	0.059***	1				
Dual	0.097***	-0.123***	1			
Big4	0.061***	0.156***	-0.058***	1		
Heavy	-0.052***	0.052***	-0.026***	-0.004	1	
SOEs	0.009	0.284***	-0.283***	0.136***	0.015*	1

Notes: Corporate Financial Performance (CFP), Carbon Disclosure Quality (CDQ), Internal Control (IC), Firm Size (Size), Leverage (LEV), Institutional Investor Ownership (IIO), Independent Director Ratio (IDR), Ownership Concentration (Top1), CEO Duality (Dual), Audit Quality (Big4), Heavily Polluting Industry (Heavy), State-Owned Enterprises (SOEs). *, **, and *** indicate significance at the 10%, 5%, and 1% levels.

Source: Own elaboration.

Table 5. Fixed Effects Estimation of Baseline Effect

Variable	(1) CFP	(2) CFP
L1.CDQ	-0.049 (0.071)	0.151** (0.068)
Size		-1.134*** (0.072)
LEV		0.439*** (0.099)
IIO		0.018*** (0.001)
IDR		0.005** (0.002)
Top1		-0.014*** (0.002)
Dual		-0.059** (0.026)
Big4		0.038 (0.060)
Heavy		0.121 (0.304)
SOEs		-0.175** (0.061)
Firm FE	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes
Constant	1.320*** (0.343)	11.742*** (0.738)
Observations	15.834	15.834
Within R²	0.222	0.293

Note: Corporate Financial Performance (CFP), Carbon Disclosure Quality lagged One Year (L1.CDQ), Firm Size (Size), Leverage (LEV), Institutional Investor Ownership (IIO), Independent Director Ratio (IDR), Ownership Concentration (Top1), CEO Duality (Dual), Audit Quality (Big4), Heavily Polluting Industry (Heavy), State-Owned Enterprises (SOEs). All regressions are estimated using firm FE with standard errors clustered by firm. Robust standard errors are reported in parentheses. 0.000 represents a value less than 0.001. *, **, and *** indicate significance at the 10%, 5%, and 1% levels.

Source: Own elaboration.

Correlation coefficients indicate that there is a generally moderate association between the independent variables and control variables. Notably, the highest observed pairwise correlation coefficient occurs between two control variables, *Top1* and *IIO* ($r = 0.608^{**}$), while the correlation coefficient between *CDQ* and *Size* is also relatively high ($r = 0.522^{***}$). All correlation coefficients are within acceptable ranges [91], indicating that multicollinearity is unlikely to bias the regression estimates.

Overall, while the correlation matrix reveals some significant bivariate associations, these preliminary results do not account for unobserved firm-level heterogeneity, time effects, or industry-specific factors. Therefore, *FE* and robust standard errors are employed in the multiple regression analysis to more rigorously test the hypothesized relationships.

Baseline Regression

Table 5 presents the baseline regression results of the three-way *FE* model analyzing the relationship between *CDQ* and *CFP*, controlling for unobservable firm-, year-, and industry-specific heterogeneity. To ensure the robustness of the inferences, standard errors are clustered at the firm level, a common method in panel data analysis that effectively mitigates potential heteroskedasticity and serial correlation within firms [92].

Model (1) shows the effect of lagged *CDQ* on *CFP* without additional firm-level control variables. The coefficient is negative but not significant ($\beta = -0.049$), consistent with the simple Pearson correlation reported in Table 4, which indicates a negative relationship between *CDQ* and *CFP* at the 1% significance level.

However, once firm characteristics (such as *Size*, *LEV*, *IIO*, *IDR*) and governance attributes are included in Model (2), the coefficient of lagged *CDQ* becomes positive and significant at the 5% level ($\beta = 0.151$), suggesting that higher-quality carbon disclosure contributes to better financial performance after controlling for relevant firm fundamentals.

This shift in the coefficient sign is consistent with omitted-variable bias in bivariate analysis. The negative and significant Pearson correlation reflects uncontrolled cross-firm heterogeneity. When firm, year, and industry fixed effects are included in Model (1), the coefficient becomes statistically insignificant, indicating that the unconditional correlation is driven by unobserved firm-specific characteristics. After further accounting for financial and governance attributes, the true within-firm effect of improving carbon disclosure quality emerges as positive and significant. Therefore, the multivariate fixed-effects specification provides a more reliable estimate of the relationship between *CDQ* and *CFP*. This pattern aligns with the findings of Yu and Xiao [59] and Zhu et al. [2], who also noted that improving *ESG* or carbon disclosure, after appropriately controlling for governance and structural factors, can enhance stakeholder confidence and increase firm value.

These results reinforce the core argument of stakeholder theory: transparent and high-quality carbon disclosure conveys signals of environmental responsibility and openness, helping to alleviate stakeholder concerns, strengthen legitimacy, and reduce information asymmetry. In turn, this can attract long-term investors, mitigate regulatory risks, and enhance corporate reputation, ultimately supporting sustained financial returns [27; 41].

Regarding control variables, *Size* is negatively and significantly correlated with *CFP*, which may indicate that larger firms face stricter external oversight and potential diseconomies of scale, as noted by Yu and Xiao [59] and Zhu et al. [2]. *LEV* and *IIO* exhibit positive and significant effects, suggesting that firms with prudent financial leverage and strong institutional oversight often achieve better performance, consistent with prior governance research [60]. The negative effects of *Dual* and *SOEs* status further highlight the potential for agency costs and political costs to erode financial returns, echoing the observations of Shah et al. [60].

To assess potential multicollinearity issues, a variance inflation factor (*VIF*) test was performed after the baseline regression. The results show that the *VIF* values for all variables are well below the commonly accepted threshold of 10 [93]. The highest *VIF* value observed is 2.27, with an average *VIF* value of approximately 1.47. Therefore, collinearity did not pose a concern in the estimated models.

Table 6. System GMM Estimation Results

Variable	CFP
<i>L1.CDQ</i>	0.674** (0.199)
Controls	Yes
Year FE	Yes
Instruments	Collapsed
No. of instruments	23
AR (1) p-value	0.000
AR (2) p-value	0.979
Hansen p-value	0.534
Wald p-value	0.000
Observations	15.834

Note: Corporate Financial Performance (CFP), Carbon Disclosure Quality lagged One Year (*L1.CDQ*). Controls include *Size*, *LEV*, *IIO*, *IDR*, *Top1*, *Dual*, *Big4*, *Heavy*, *SOEs*. Control variables slightly adjusted to match instrumental variable settings in different models. Standard errors are reported in parentheses. 0.000 represents a value less than 0.001. *, **, and *** indicate significance at the 10%, 5%, and 1% levels.

Source: Own elaboration.

Overall, the baseline regression results provide empirical support for H1, indicating that higher *CDQ* can create *CFP* by meeting stakeholder expectations and strengthening stakeholder relationships, aligning with stakeholder-oriented governance frameworks.

Addressing Endogeneity

To mitigate potential endogeneity issues (which may arise from reverse causality, simultaneity, or omitted variable bias), this study employs a two-step system generalized method of moments (*GMM*) approach, which is suitable for dynamic panel data settings where explanatory variables may be endogenous [94; 95]. Specifically, system *GMM* utilizes internal instrumental variables by employing lagged levels and differences of the endogenous dependent variable, thereby effectively controlling for unobserved firm-level heterogeneity and dynamic feedback effects. Consistent with previous *ESG* research [96], the lagged *CDQ* index is treated as a potential endogenous variable and subjected to instrumental variable treatment accordingly. Control variables are included to isolate the net effect of *CDQ* on *CFP*.

The results presented in Table 6 demonstrate that the lagged *CDQ* coefficient remains positive and statistically significant at the 5% significance level ($\beta = 0.674$), indicating that higher-quality carbon disclosure still has a positive impact on *CFP* after controlling for potential endogeneity.

This finding reinforces the baseline regression results and emphasizes the robustness of the positive relationship between *CDQ* and *CFP* after correcting for potential biases. The Arellano – Bond AR (1) and AR (2) tests confirmed the absence of second-order serial correlation in the difference residuals (AR (2) $p = 0.979$), supporting the validity of the instrumental variables. The Hansen *J* statistic ($p = 0.534$) did not reject the null hypothesis of instrumental variable exogeneity, indicating that the model specification is reasonable and the instrumental variables are valid. Additionally, the significant Wald statistic further supports the joint significance of the explanatory variables.

In summary, the system *GMM* estimation confirms the robustness of the main findings and alleviates concerns about endogeneity, providing stronger empirical support for H1.

Moderating Effect of Internal Control

Table 7 presents the regression results that demonstrate the moderating effect of *IC* on the relationship between *CDQ* and *CFP*. To minimize potential multicollinearity, both lagged *CDQ* and lagged *IC* were mean-centered prior to constructing the interaction term, following the method proposed by Aiken et al. (1991). The calculated *VIF* indicate no severe multicollinearity, with all values well below the conventional threshold of 10 (maximum *VIF* = 2.34; average *VIF* = 1.41) [93].

Table 7. Fixed Effects Estimation of the Moderating Effect of Internal Control

Variable	(I) <i>CFP</i>	(II) <i>CFP</i>
<i>L1.CDQ_c</i>	-0.066 (0.071)	0.135** (0.068)
<i>L1.IC_c</i>	0.040*** (0.011)	0.059*** (0.010)
<i>L1.CDQ_c · L1.IC_c</i>	0.058 (0.043)	0.085** (0.043)
<i>Controls</i>	No	Yes
<i>Firm FE</i>	Yes	Yes
<i>Year FE</i>	Yes	Yes
<i>Industry FE</i>	Yes	Yes
Constant	1.296*** (0.338)	12.090*** (0.735)
Observations	15.834	15.834
Within R²	0.223	0.296

Note: Corporate Financial Performance (*CFP*), Carbon Disclosure Quality lagged One Year and Mean-Centred (*L1.CDQ_c*), Internal Control lagged One Year and Mean-Centred (*L1.IC_c*), The Interaction Term of *L1.CDQ_c* and *L1.IC_c* (*L1.CDQ_c · L1.IC_c*), Controls include Size, LEV, IIO, IDR, Top1, Dual, Big4, Heavy, SOEs. All regressions are estimated using firm FE with standard errors clustered by firm. Robust standard errors are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels.

Source: Own elaboration.

Model (I) reports the moderation results without adding other control variables. The coefficient of the interaction term ($L1.CDQ_c \cdot L1.IC_c$) is positive but not statistically significant, indicating that the moderating effect of *IC* cannot be fully captured when firm-level attributes are ignored. However, when Model (II) includes all control variables, the interaction term becomes positive and significant at the 5% level ($\beta = 0.085$). This suggests that, after controlling for governance, ownership, and firm characteristics, *IC* plays an important moderating role in strengthening the positive association between *CDQ* and *CFP*.

This result aligns with stakeholder theory, which posits that effective internal governance mechanisms can enhance the credibility and effectiveness of external information disclosure practices [45]. Effective *IC* not only ensures the disclosure of carbon-related information but also guarantees its reliable generation, verification, and alignment with stakeholder expectations [45]. By improving information quality and consistency, effective *IC* help build stakeholder trust, reduce information asymmetry, and alleviate concerns about greenwashing or speculative reporting [52; 53]. This, in turn, amplifies the positive valuation effect of *CDQ* on *CFP*.

The main significant positive effect of *IC* ($\beta = 0.059$, $p < 0.01$) further indicates that companies with more effective *IC* typically achieve better *CFP*, consistent with previous research findings [44]. Combined with the significant interaction effect, these results support H2, which posits that the positive impact of *CDQ* on *CFP* is stronger when *IC* is more effective.

Robustness Tests

To ensure the robustness and generalizability of the core research findings, this study adopted two complementary robustness strategies. First, the dependent variable was replaced with an alternative indicator of *CFP*, namely *MB*, which provides an additional market-based perspective on corporate value [59; 60]. Second, the sample period was adjusted by excluding data from 2020–2021 to mitigate the potential impact of the unprecedented economic turmoil caused by the COVID-19 pandemic [30; 41; 98].

Table 8 reports the results of the robustness tests. Columns (a) and (A) display the baseline effect estimates and moderation effect estimates, respectively, with *MB* as the dependent variable. The results are consistent with the main findings: the lagged *CDQ* coefficient remains significant-

Table 8. Robustness Tests Using Alternative Dependent Variable and Adjusted Sample Period

Variable	(a) <i>CFP (MB)</i>	(A) <i>CFP (MB)</i>	(b) <i>CFP (excluding 2020–2021)</i>	(B) <i>CFP (excluding 2020–2021)</i>
<i>L1.CDQ</i>	0.149** (0.068)		0.119* (0.061)	
<i>L1.CDQ_c</i>		0.133* (0.068)		0.096 (0.061)
<i>L1.IC_c</i>		0.059*** (0.010)		0.064*** (0.010)
<i>L1.CDQ_c</i> × <i>L1.IC_c</i>		0.082* (0.042)		0.116** (0.043)
<i>Controls</i>	Yes	Yes	Yes	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes
<i>Year FE</i>	Yes	Yes	Yes	Yes
<i>Industry FE</i>	Yes	Yes	Yes	Yes
Constant	11.680*** (0.738)	12.027*** (0.735)	12.832*** (0.691)	13.186*** (0.690)
Observations	15.834	15.834	13.398	13.398
Within R^2	0.291	0.294	0.337	0.342

Note: Corporate Financial Performance (CFP), Market-to-Book Ratio (MB), Carbon Disclosure Quality lagged One Year (*L1.CDQ*), Carbon Disclosure Quality lagged One Year and Mean-Centred (*L1.CDQ_c*), Internal Control lagged One Year and Mean-Centred (*L1.IC_c*), The Interaction Term of *L1.CDQ_c* and *L1.IC_c* (*L1.CDQ_c* · *L1.IC_c*). Controls include Size, LEV, IIO, IDR, Top1, Dual, Big4, Heavy, SOEs. All regressions are estimated using firm FE with standard errors clustered by firm. Robust standard errors are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels.

Source: Own elaboration.

ly positive ($\beta = 0.149$, $p < 0.05$), and the interaction term remains significantly positive at the 10% level ($\beta = 0.082$, $p < 0.1$). This suggests that the positive impact of *CDQ* on *CFP* and the moderating effect of *IC* are not sensitive to the choice of financial performance proxy.

Columns (b) and (B) show the estimates after excluding pandemic years from the sample. The results are broadly consistent. In the baseline model, the lagged *CDQ* coefficient remains significantly positive at the 10% level ($\beta = 0.119$), and the moderating effect of *IC* is enhanced, with the interaction term significant at the 5% level ($\beta = 0.116$). This implies that the positive moderating effect of *IC* remains valid even when considering the structural shocks that companies may have faced in terms of operations and information disclosure during the pandemic.

In summary, these results further support that robust governance structures and reliable information disclosure practices remain important drivers of *CFP* even under changing market conditions. This relationship persists across different performance proxy indicators and subsamples, indicating that the empirical results are not a product of model specification, measurement selection, or specific period shocks.

Conclusion

This study investigates how *CDQ* affects *CFP*, with a particular focus on the moderating role of *IC* in the context of stakeholder theory. Based on a balanced panel of Chinese A-share listed companies from 2010 to 2023, this study adopts three-way *FE* estimations and system *GMM* to address endogeneity and unobserved heterogeneity. The results yield several important insights.

First, baseline regression results confirm that higher *CDQ* is positively associated with *CFP* after controlling for key firm-level variables. This finding supports the view that transparent and credible disclosure of carbon emission information reduces information asymmetry, strengthens corporate legitimacy, and fosters stakeholder trust – consistent with a stakeholder-oriented governance perspective.

Second, the moderating effect analysis reveals that internal control (*IC*) significantly reinforces this positive relationship. Firms with more effective *IC* systems are better positioned to ensure the integrity and reliability of carbon-related disclosures, thereby boosting stakeholder confidence and facilitating the conversion of sustainability transparency into tangible financial benefits.

Finally, a series of robustness checks – employing alternative measures of financial performance and varying the sample period—yield consistent results, reinforcing the validity of the main findings.

This study makes three specific contributions that are also of practical significance beyond the academic field. First, it expands the stakeholder theory and shows how carbon disclosure can be a tool used to strengthen stakeholder relationships and achieve financial returns based on Chi-

na's unique institutional environment. Second, it enriches the governance literature, revealing that effective *IC* can not only reduce opportunistic behavior, but also serve as a governance infrastructure to amplify the value creation effect of high-quality disclosure. Third, from a methodological perspective, this study develops a context-adapted multidimensional *CDQ* evaluation index supported by Python-based automatic text retrieval and scoring. The index provides a transparent and replicable tool for assessing disclosure quality for policymakers, regulators, and investors, which can provide reference for sustainable development standards, disclosure guidelines, and responsible investment screening.

These contributions carry clear policy implications. For policymakers and regulators, the results emphasize the importance of strengthening internal governance frameworks to ensure that mandatory and voluntary disclosures are meaningful and credible. For investors, this study shows that companies with robust internal controls and high *CDQ* may be more capable of creating sustainable financial value, providing practical guidance for ESG-focused investment strategies. For corporate managers, the findings highlight the need to integrate effective *IC* measures alongside disclosure initiatives to maximize the economic benefits of sustainability reporting.

However, this study also has certain limitations. Although the *CDQ* index was constructed using automated Python scripts for systematic text retrieval and scoring, its accuracy may be affected by the design of keyword dictionaries and semantic rules, which may ignore subtle expressions. Future research could integrate advanced natural language processing (*NLP*) or artificial intelligence-driven techniques to improve the measurement method to capture deeper contextual information and sentiment. In addition, this study focuses only on Chinese listed companies; future work could test the proposed framework in different institutional settings or explore how other governance dimensions (such as board diversity or external assurance) affect the relationship between *CDQ* and *CFP*.

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