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The Impact of Climate Risks on Corporate Green Governance: Evidence from China

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Abstract: *Against the backdrop of escalating global concern over climate change, promoting corporate green governance has become a critical issue for both the business community and academia. This study empirically examines the impact of climate risk on corporate green governance using a sample of Chinese A-share listed companies from 2011 to 2023. The results indicate that climate risk significantly promotes corporate green governance. This positive effect operates through two key mechanisms: enhancing green innovation and improving the quality of environmental information disclosure. Furthermore, heterogeneity analyses reveal that the effect of climate risk on green governance is more pronounced among firms with higher levels of artificial intelligence application and stronger internal control quality. Overall, this study not only provides a theoretical explanation for the causal relationship between climate risk and corporate green governance but also offers practical insights for firms seeking to establish climate-adaptive governance systems and for policymakers aiming to design differentiated environmental regulations.*

Keywords: *Climate risk; Green governance; Green innovation; Environmental information disclosure*

1. Introduction

The World Meteorological Organization's State of the Global Climate 2023 report indicates that the global climate system experienced an accelerated transformation throughout 2023. Rapid increases in global average temperatures, persistently rising greenhouse gas concentrations, and record-breaking sea surface temperatures and sea level rise collectively underscore the escalating severity of the global climate crisis[1]. In response to this challenge, countries around the world have committed to coordinated efforts to address climate change. For example, the international community signed the Paris Agreement, pledging collective global action to mitigate climate risks[2]. Against this backdrop, climate-related issues have exerted profound impacts on corporate production and operations[3].Taking China as an illustrative case, climate disasters such as the 2021 Henan torrential rains and Typhoon Mawar in 2024 caused substantial economic losses for Chinese enterprises, resulting in supply chain disruptions, damage to fixed assets, and even operational paralysis. At the same time, climate challenges have also generated new "opportunities" for business development[4]. Governments worldwide have increased investments in renewable energy and supported corporate initiatives aimed at energy conservation and emissions reduction, thereby fostering rapidly expanding green markets. For enterprises, pursuing green and sustainable development is not only a strategy for mitigating climate risks but also a critical pathway to enhancing long-term competitiveness[5].In this context, green governance, as an emerging management paradigm, has become increasingly important for corporate sustainability[6]. However, Chinese enterprises still face challenges such as insufficient green management practices, limited effectiveness of green incentives, and underdeveloped green risk prevention systems. How to effectively advance corporate green governance therefore remains an open question. In particular, whether climate risk serves as a driving force for promoting corporate green governance has yet to be fully explored. Accordingly, examining how climate risk influences corporate green governance and its underlying mechanisms can not only deepen understanding of the economic consequences of climate risk but also provide theoretical and practical guidance for enterprises worldwide in achieving sustainable green development.

Climate risk, as a systemic risk induced by global climate change, has emerged as a central topic in academic research in recent years. It is generally categorized into physical risks—such as the direct impacts of extreme weather events on assets and supply chains—and transition risks, including

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stranded assets arising from policy adjustments and technological shifts[7]. Existing studies suggest that climate risk exhibits a pronounced "double-edged sword" effect on corporate economic outcomes, posing significant challenges while simultaneously catalyzing transformational opportunities.On the negative side, climate risk increases financial and operational uncertainty for firms. For example, it exacerbates financing constraints[8] and elevates stock price crash risk[9]. Moreover, Lin et al. demonstrate that climate risk undermines financial stability by deteriorating corporate performance and increasing non-performing loan ratios[10], thereby constraining firms' capacity for green investment. Climate risks may also disrupt supply chains and erode asset values[11]. On the positive side, climate risk can incentivize improvements in corporate sustainability performance. Yin et al. find that rising climate risks compel firms to enhance ESG performance[12]. Heightened climate risks also attract green investors, thereby stimulating green technological innovation[13] and accelerating green and low-carbon transitions [14]. Furthermore, Wang et al. document that climate risk significantly promotes corporate social responsibility by elevating public expectations[15]. While prior research has extensively examined the economic consequences of climate risk for enterprises, the relationship between climate risk and corporate green governance remains insufficiently explored. How, then, does climate risk influence corporate green governance, and through what mechanisms does this effect occur?

The essence of corporate green governance lies in promoting green innovation and transforming business operations through the establishment of a multi-stakeholder collaborative governance framework led by enterprises. This process emphasizes the application of advanced technologies, diversified instruments, and innovative governance models to facilitate the creative generation of green value within firms. Existing studies have explored the driving mechanisms of corporate green governance primarily from three perspectives: policy, firm-level characteristics, and market forces.At the policy level, clear and stable environmental regulations effectively guide corporate green governance practices[16], whereas policy uncertainty may generate nonlinear effects that weaken firms' incentives to engage in green governance[17]. Green finance policies, for example, significantly enhance corporate green performance through credit-based incentives and financial support mechanisms[18]. At the firm level, executive power plays a facilitating role in green governance, particularly when top management exhibits strong social responsibility awareness[19]. Moreover, the application of artificial intelligence promotes green governance by optimizing asset allocation and enhancing market valuation[20], while strong ESG performance directly improves green total factor productivity, thereby reinforcing incentives for green governance[21]. From a market perspective, mechanisms such as green bond issuance[22] and institutional investor monitoring[23] further strengthen green governance through financing access and external governance pressure. In addition, the development of the digital economy fosters the diffusion of green concepts within industries by upgrading industrial structures, thereby indirectly promoting corporate green governance[24]. Despite these advances, existing research has yet to systematically examine the relationship between climate risk and corporate green governance. Accordingly, this study seeks to investigate the impact of climate risk on corporate green governance, thereby filling an important gap in the literature and providing a meaningful extension to existing research.

Relative to the existing literature, this study makes three primary contributions. First, it systematically extends the theoretical understanding of the relationship between climate risk and corporate green governance. Prior research has largely concentrated on the "double-edged sword" effects of climate risk on financial performance[8–9], ESG outcomes[12], or technological innovation[13], while paying limited attention to how climate risk shapes strategic transformations in firms' internal governance structures. By integrating risk aversion theory with institutional pressure theory, this study incorporates climate risk into the analytical framework of green governance. It demonstrates that climate pressure, operating through a "risk–behavior–governance" transmission mechanism, compels firms to transform green governance from a passive compliance-oriented response into an active value-creation mechanism, thereby filling a critical gap in the causal understanding of climate risk and governance dynamics. Second, this study innovatively identifies a synergistic dual-mediation mechanism. Moving beyond single-path explanations, the findings reveal that climate risk promotes green governance through two complementary channels: green innovation–driven resource capability restructuring and environmental information disclosure–based signaling transmission. This evidence deepens understanding of the complex mechanisms underlying climate-related governance responses and provides new empirical insights into the so-called "governance black box." Finally, through heterogeneity analysis, this research identifies important boundary conditions shaping the effectiveness of green governance. The results show that climate risk exerts a stronger promotional effect on green governance among firms with higher levels of artificial intelligence application and stronger internal control quality. This finding highlights the synergistic roles of technological empowerment and

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institutional safeguards in enhancing corporate climate resilience. By moving beyond traditional "one-size-fits-all" governance approaches, the study suggests that policy design should account for heterogeneity in firms' digital foundations and governance maturity, offering targeted guidance for the implementation of differentiated and tiered green governance strategies.

2. Theoretical analysis and research hypotheses

2.1. Climate Risk and Green Governance

This study systematically elucidates the mechanisms through which climate risks influence corporate green governance by adopting an integrated analytical framework that combines risk aversion theory and institutional pressure theory.

First, drawing on risk aversion theory, climate risks compel firms to promote green governance practices through dual pathways. With respect to physical risks, the increasing frequency of extreme weather events and environmental disasters directly impair corporate physical assets and disrupt supply chains, resulting in production interruptions, rising operational costs, and asset value depreciation, thereby substantially increasing operational uncertainty[25]. In terms of transition risks, environmental regulations and industrial policies implemented by governments to address climate change impose stricter compliance requirements on high-carbon enterprises by raising regulatory standards, intensifying enforcement, and accelerating the phase-out of outdated production capacities[26]. Under heightened climate-related uncertainty, firms increasingly perceive green governance as a critical risk-mitigation mechanism to reduce exposure through proactive environmental management. In practice, firms establish comprehensive environmental management systems, set up sustainability committees, integrate climate risk considerations into core decision-making agendas, and implement end-to-end environmental governance frameworks. Explicit environmental and carbon reduction targets are incorporated into executive performance evaluation systems[27]. From a resource allocation perspective, firms continuously increase investments in green technology research and development, clean production upgrades, and circular economy initiatives, reallocating strategic resources toward low-carbon sectors[28]. Furthermore, the deployment of digital technologies enables real-time monitoring of energy consumption, emissions, and environmental indicators, ensuring sustained compliance with both internal governance requirements and external regulatory standards while enhancing data integrity and management effectiveness[29]. Through these governance-oriented decision-making mechanisms and organizational arrangements, green governance fundamentally enhances corporate resilience. This approach represents not merely a defensive response to regulatory pressure, but a strategic pathway through which firms optimize governance structures to channel resources toward green transformation, thereby securing long-term value creation and advancing sustainable corporate development.

Second, from the perspective of institutional pressure theory, external institutional pressures constitute a key driving force behind firms' adoption and deepening of green governance practices. This pressure operates through three primary channels. First, government-mandated environmental laws, regulations, and disclosure requirements compel firms to establish formal green governance systems in order to maintain organizational legitimacy and avoid regulatory sanctions[30]. Typical practices include the establishment of dedicated sustainability committees, the incorporation of environmental compliance indicators into executive performance evaluations, and the development of internal carbon accounting and auditing mechanisms. Second, standards and norms promulgated by capital markets, industry associations, and professional institutions exert significant influence. To gain access to green financing, enhance market reputation, and meet the expectations of key stakeholders such as investors, firms proactively align their governance practices with these external benchmarks. This alignment is reflected in strengthened board-level oversight of environmental issues, the publication of comprehensive sustainability reports, and the continuous refinement of environmental management systems[31]. Third, competitive imitation and benchmarking further reinforce the diffusion of green governance practices. When leading firms within the same industry or region achieve competitive advantages through advanced green governance, other firms tend to emulate their governance structures and management models to maintain competitive parity and avoid legitimacy deficits[32]. Such practices include adopting environmental management system certifications, implementing standardized green procurement policies, and establishing comparable climate risk management positions. Collectively, these institutional pressures constitute a powerful institutional field that compels firms to institutionalize and standardize green governance practices, not solely for

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economic efficiency, but to secure external recognition and legitimacy. Consequently, green governance is transformed from a discretionary managerial initiative into a necessary and strategic organizational response to climate-related challenges.

Based on the above analysis, this paper proposes the following hypothesis.

H1: Climate risk significantly promotes corporate green governance.

2.2. The impact Mechanisms of Climate Risk and Green Governance

The influence of climate risk on corporate green governance is primarily transmitted through two mechanisms: enhancing green innovation and improving the quality of environmental information disclosure. These two pathways jointly explain how firms translate external climate-related risks into tangible processes of green governance upgrading, operating respectively through internal resource reconfiguration and external signal transmission. The following sections elaborate on the specific operational logic underlying these two key mechanisms.

Green innovation constitutes the foundational resources and capabilities through which climate risk drives corporate green governance. According to the resource-based view (RBV), sustainable competitive advantage arises from the possession of strategic resources that are valuable, scarce, difficult to imitate, and non-substitutable. As an exogenous shock, climate risk reveals structural vulnerabilities embedded in traditional corporate resource bases—such as carbon-intensive assets and linear production processes—thereby prompting firms to reconfigure and accumulate new green resources through innovation. This process systematically enhances corporate green governance levels[33]. Specifically, under heightened climate risk pressures, firms increase investment in green innovation technologies, including clean production, pollution control, and recycling technologies, to enhance supply chain resilience and mitigate asset exposure by improving energy efficiency and resource circularity[34]. In response to evolving environmental regulations and shifting market demand, firms also proactively develop low-carbon technologies and digital environmental management models. The continuous advancement of these green innovations not only generates novel strategic resources but also strengthens firms' dynamic green capabilities. As green innovation activities expand, firms must undertake corresponding adjustments to existing governance arrangements. To effectively allocate, maintain, and utilize these emerging green resources, firms are compelled to systematically upgrade their internal green governance structures[35]. Such upgrades include establishing dedicated green innovation management units, optimizing decision-making and resource allocation mechanisms for green projects, and embedding green innovation performance indicators into evaluation and incentive systems[36]. Overall, climate risk motivates firms to renew strategic resources and build capabilities through green innovation, thereby necessitating the development of more structured and adaptive green governance frameworks to manage these newly formed resources and capabilities. This transformation enables firms to shift from passive climate risk response toward proactive green transformation, reinforcing green governance as a core strategic function rather than a reactive compliance mechanism.

Based on the above analysis, this paper proposes the following hypotheses.

H2a: Climate risks significantly promote green governance by enhancing corporate green innovation.

Climate risk can strengthen corporate green governance by improving the quality of environmental information disclosure. Drawing on signaling theory, firms operating in highly uncertain markets have strong incentives to communicate credible information to external stakeholders in order to gain trust, secure capital, and maintain legitimacy. Intensifying climate risk significantly heightens the attention and information demands of investors, regulators, and the public regarding firms' environmental management quality[37]. In this context, high-quality and transparent environmental disclosure becomes a central signal through which firms demonstrate the effectiveness of their green governance and their commitment to climate risk mitigation. By proactively disclosing detailed information on environmental management practices, green operational processes, and environmental performance outcomes, firms seek to signal regulatory compliance to authorities, operational stability and long-term value to capital markets, and social responsibility to the broader public[31]. However, the expansion in both the scope and depth of environmental disclosure also generates a powerful internal governance pressure. To ensure the credibility of externally disclosed information, firms must establish robust internal green governance infrastructures. For example, accurate carbon footprint accounting requires the development of comprehensive data monitoring and statistical systems spanning the entire value chain[38]. Similarly, detailed climate risk management disclosures necessitate integrating climate-related

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issues into substantive board-level deliberations and clearly defining managerial responsibilities for green practices. Reporting progress toward carbon reduction targets further requires the decomposition of objectives, continuous performance tracking, and the publication of third-party verified ESG reports[39]. Through these processes, environmental disclosure is transformed from a potentially symbolic external practice into a substantive mechanism that drives refined and transparent internal green governance. Moreover, external stakeholders' scrutiny, verification, and feedback on disclosed information generate sustained external oversight pressure, compelling firms to continuously reinforce their institutional foundations, management processes, and execution efficiency in green governance.

Based on the above analysis, this paper proposes the following hypothesis:

H2b: Climate risk significantly promotes green governance by improving the quality of corporate environmental information disclosure.

3. Methology

3.1. Sample Selection and Data Source

This study examines Chinese A-share listed companies from 2011 to 2023, excluding ST or *ST companies, delisted samples, financial firms, and companies with anomalous or missing data for key variables, or discontinuous data within the sample period. To mitigate bias from extreme values and ensure subsequent results' accuracy, all continuous variables underwent 1% tail trimming. Following data processing and outlier removal, 21,440 valid observations were obtained. All data were sourced from corporate annual reports, the CSMAR database, and the CNRDS database.

3.2. Variable Selection

3.2.1. Dependent variable

Green Governance Performance (GGP) is employed as the dependent variable in this study. Following the measurement approach proposed by Feng et al.[20], this study adopts the Janis–Fadner (JF) coefficient to quantify corporate green governance performance. Specifically, p denotes the firm's positive green governance score, which is calculated based on the number of criteria satisfied under positive scoring standards, with each criterion assigned a value of 1. The positive criteria include obtaining ISO 14000 series certification, receiving green awards, compliance with pollution emission standards, environmental governance scores ranking in the top 30% of the sample based on ESG ratings, and achieving the highest environmental management system rating in ESG assessments. Each positive criterion is coded as 1 if satisfied and 0 otherwise. Conversely, q represents the negative green governance score, calculated based on the number of criteria met under negative scoring standards, with each criterion assigned a value of −1. Negative criteria include environmental administrative penalties, environmental complaints, sudden environmental incidents, non-compliance with pollution emission standards, environmental governance scores ranking in the bottom 30% of the sample in ESG ratings, and receiving the lowest environmental management system rating in ESG assessments. Each negative criterion is coded as −1 if satisfied and 0 otherwise. The variable r is defined as the sum of p and the absolute value of q (i.e., $r = p + |q|$). The GGP index ranges from −1 to 1, with higher values indicating stronger green governance performance. The specific calculation method is presented in Formula (1).

$$GGP=\begin{cases}(p-p\times|q|)\div r^2, & if\ p>|q| \\ (p\times|q|-q^2)\div r^2, & if\ p<|q| \\ 0, & if p=|q|\end{cases} \tag{1}$$

3.2.2. Independent variable

Climate risk (CR) is employed as the key explanatory variable in this study. Following the measurement approach proposed by Li et al.[28], climate risk is measured by calculating the proportion of climate risk–related keywords appearing in firms' annual reports. First, annual reports of Chinese A-share listed companies from 2011 to 2023 were obtained from the website of the China Securities Regulatory Commission and subjected to textual analysis. Second, using a climate risk lexicon comprising 98 keywords (see Table 1), the annual report texts were processed using the Jieba Chinese word segmentation tool. Climate risk–related terms were identified through word segmentation, and their cumulative frequencies were calculated to obtain the total frequency of climate risk keywords.

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Finally, climate risk was quantified as the ratio of climate risk keyword frequency to the total word count of each annual report. Higher values of this measure indicate greater exposure to climate risk at the firm level.

Table 1 Climate Risk Keywords

Risk Type	Word Set
Serious Risks	typhoon, disaster, drought and flood, drought, severe, extreme, strong wind, frost, flooding, hurricane, urban waterlogging, storm, dust, debris flow, freezing, snow disaster, drought situation, landslide, flood, hail, tornado, rainstorm, rain and snow, heavy snow, freeze injury, flood disaster, earthquake, severe cold, tsunami, heavy rain, sandstorm, intense rainfall, freeze, water disaster (34)
Chronic Risks	weather, humidity, water temperature, cooling, temperature, rainfall, cold, air temperature, heavy rain, precipitation, rainy season, rainwater, rain situation, overcast, winter, flood season, extreme cold, high humidity, water regime, sunlight, water shortage, water level, cold, surface, cold wave, climate, groundwater, flood situation, sedimentation, water storage (30)
Transition Risks	energy, clean, energy saving, ecology, environment, intensive, solar energy, upgrading, transformation, recycling, utilization, wind power, natural gas, nuclear power, efficiency, fuel, efficiency, regeneration, emission reduction, efficiency, environmental protection, green, consumption reduction, fuel, low carbon, water saving, photovoltaic, transformation, fuel consumption, high efficiency, power consumption, energy consumption, photovoltaic, wind power, (34)

3.2.3. Mechanism Variables

Green Innovation (GI) serves as the mechanism variable in this study. Following the measurement approach of Liu et al.[40], it is assessed by taking the natural logarithm of the sum of the number of green patents applied for by the firm in the current year plus one.

Environmental Information Disclosure (EID) is employed as the instrumental variable in this study. Following the measurement approach proposed by Lv et al.[41], EID is measured using five-dimensional disclosure scores obtained from the CSMAR Environmental Information Disclosure Database for listed companies. These dimensions include Environmental Management Disclosure, Environmental Regulation and Certification Disclosure, Environmental Information Disclosure Channels, Environmental Liability Disclosure, and Environmental Performance and Governance Disclosure.A total of 25 indicators are evaluated. For non-monetary disclosure items, a score of 2 is assigned if the relevant information is disclosed and 0 otherwise. For monetary disclosure items, a score of 2 is assigned when both quantitative and qualitative information is provided, while a score of 1 is assigned if only qualitative information is disclosed. The individual indicator scores are aggregated and logarithmically transformed. Higher values of this index indicate higher-quality environmental information disclosure.

3.2.4. Control Variables

Based on prior research, we introduced control variables including firm size (Size), firm age (Age), leverage ratio (Lev), book-to-market ratio (Bm), ownership concentration (Own), return on assets (Roa), fixed asset ratio (Fixed), dual role (Dual), and board size (Board) to control for other factors influencing green governance.

Table 2 lists the variables examined in this study and their corresponding measurement methods.

Table 2. Variable definition and calculation.

Variable type	Variable name	Code	Measurement Method
Dependent Variable	Green Governance Performance	GGP	Janis-Fadner coefffcient (J-F coefffcient)
Independent Variable	Climate Risk	CR	Total word frequency of 98 "climate risk" words as a proportion of total word frequency of annual report
Mechanism Variables	Green innovation	GI	Natural logarithm of the number of green patents plus 1
	The quality of environmental information disclosure	Eid	Content Scoring Method Score Summary
Control Variables	Firm Size	Size	Log(total assets+1)
	Firm Age	Age	Years of corporate existence
	Financial leverage	Lev	Total liabilities / Total assets
	Fixed Asset Ratio	Fixed	Fixed assets / Total assets
	Book-to-Market Ratio	Bm	Book value / Total market value
	Ownership Concentration	Own	The ratio of shares held by the top five shareholders to total shares
	Profitability	Roa	Net profit / Total assets
	Dual-role	Dual	Whether the chairman and general manager are the same person
	board members	Board	Natural logarithm of the number of board members plus on

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3.3. Model setting

This paper employs a panel data model to examine the impact of climate risks on green governance. The benchmark model is defined as follows (2):

$$GGP_{i,t}=\alpha_0+\alpha_1 CR_{i,t}+\alpha_2 \sum \text{Controls}_{i,t}+\sum Year+\sum Industry+\varepsilon_{i,t} \quad (2)$$

In this model, GGP represents the dependent variable green governance, CR denotes the Independent variable climate risk, Controls signifies the control variables, and ε is the random error term. To mitigate result biases stemming from industry and time factors, the model simultaneously controls for annual fixed effects (Year) and industry fixed effects (Industry).

4. Analysis of Empirical Results

4.1. Descriptive Statistics

Table 3 presents descriptive statistics including sample size, mean, and standard deviation for key variables. As shown in Table 3, the mean value of Green Governance Practices (GGP) is 0.617, with a maximum of 1 and a minimum of -1. This indicates varying levels of green governance practices across firms. Additionally, the maximum value for climate risk (CR) is 5.560, while the minimum reaches 0, indicating that the climate risk levels among the sampled enterprises vary considerably. The data characteristics of the remaining control variables are largely consistent with existing research, suggesting that the values of these variables fall within reasonable ranges.

Table 3. Descriptive Statistic

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
GGP	21,440	0.617	0.442	-1	1
CR	21,440	0.364	0.380	0	5.560
Eid	21,440	1.963	0.892	0	3.584
GI	21,440	1.116	1.314	0	7.447
Bm	21,440	0.355	0.165	0.000670	1.290
Size	21,440	22.39	1.327	17.81	28.70
Lev	21,440	0.413	0.196	0.0143	0.998
Age	21,440	2.189	0.816	0.693	3.526
Fixed	21,440	0.201	0.152	0	0.954
Roa	21,440	0.0358	0.0761	-1.856	0.786
Own	21,440	0.533	0.152	0.0780	0.988
Dual	21,440	0.313	0.464	0	1
Board	21,440	3.650	0.132	2.727	4.394

4.2. Baseline regression

Table 4 reports the regression results examining the impact of climate risk (CR) on green governance performance (GGP). Column (1) presents the baseline regression without control variables or industry and year fixed effects. The estimated coefficient of climate risk (CR) is 0.169 and statistically significant at the 1% level. Column (2) further includes industry and year fixed effects, and the coefficient of climate risk (CR) remains positive and significant, with an estimated value of 0.099 at the 1% level. Column (3) additionally incorporates a full set of control variables; the coefficient of climate risk (CR) remains statistically significant at the 1% level, with a magnitude of 0.067.These results support our core argument that climate risk encourages firms to treat green governance as a key risk-mitigation mechanism, thereby reducing exposure through proactive environmental management. Heightened climate risk intensifies external institutional pressures, prompting firms to adopt and deepen green governance practices. To obtain external recognition and legitimacy, firms increasingly institutionalize and standardize green governance, transforming it from a discretionary management initiative into a necessary organizational strategy. Overall, the results indicate that climate risk (CR)

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exerts a significant positive effect on green governance performance (GGP), providing strong empirical support for Hypothesis 1.

Table 4. Baseline regression results

	(1)	(2)	(3)
	GGP	GGP	GGP
CR	0.169***	0.099***	0.067***
	(0.008)	(0.010)	(0.010)
Size			0.029***
			(0.003)
Age			-0.006
			(0.005)
Bm			0.053**
			(0.023)
Fixed			-0.029
			(0.025)
Roa			0.110***
			(0.042)
Lev			0.076***
			(0.024)
Own			-0.020
			(0.022)
Dual			-0.025***
			(0.006)
Board			-0.036
			(0.022)
_cons	0.555***	0.580***	0.058
	(0.004)	(0.005)	(0.100)
Control	no	no	yes
Year	no	yes	yes
Industry	no	yes	yes
N	21440	21440	21440
r2_a	0.021	0.119	0.127
Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$			

4.3. Robustness Test

4.3.1. Lag Test

The impact of climate risk (CR) on green governance (GGP) may manifest in the future. To mitigate potential reverse causality issues, the explanatory variable climate risk level is lagged by one period (L.CR). Regression results are presented in Column (1) of Table 5. The regression coefficient for climate risk (L.CR) on green governance (GGP) is 0.067 and is statistically significant at the 1% level. Consistent with the benchmark regression results, climate risk exerts a significant positive impact on green governance.

4.3.2. Replace independent variables

To validate the robustness of the benchmark regression results, this study employs the natural logarithm of the sum of one plus the climate risk keywords (CR1) from corporate annual reports as a proxy variable for climate risk levels. This approach analyzes the impact of climate risk on corporate green governance. The regression results are presented in Column (2) of Table 5. The regression coefficient for climate risk (CR1) on green governance practices (GGP) is 0.044, significant at the 1% level. Consistent with the benchmark regression findings, climate risk exerts a significant positive impact on green governance.

4.3.3. Instrumental Variables Method

This study employs the average climate risk level (CR_Ind) of enterprises within the same region and industry as an instrumental variable for two-stage least squares (2SLS) regression. This variable exhibits a direct correlation with climate risk (CR) without directly influencing corporate green governance, and it lacks direct ties to individual firms' error terms or specific circumstances, thereby demonstrating high exogeneity. The instrumental variable passed tests for weak instrumentality and over-identification, meeting the fundamental requirements for instrumental variable selection. As shown in Table 5, Column (3) data indicates a significant positive correlation between the instrumental variable (CR_Ind) and climate risk (CR). In Column (5), the regression coefficient for climate risk (CR) on corporate green governance (GGP) remains significantly positive, consistent with the benchmark

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regression results.

4.3.4. Propensity Score Matching (PSM)

Climate risks vary significantly across different enterprises, and such variations may influence regression results. To mitigate this disparity, this study employs Propensity Score Matching (PSM) for testing. First, climate risks are grouped into two categories based on the median climate risk level: enterprises with climate risks above the median are assigned a value of 1, while those below are assigned 0. Next, we selected firm size (Size), firm age (Age), debt-to-equity ratio (Lev), book-to-market ratio (Bm), ownership concentration (Own), return on assets (Roa), fixed asset ratio (Fixed), dual role (Dual), and board size (Board) as feature variables. The sample was then matched 1:1 using the nearest neighbor matching method. The matched results were then fed into the model for regression analysis. Column (5) of Table 5 reports the regression results for the PSM-matched sample. These findings align with the prior hypothesis testing results, confirming that climate risk exerts a significant positive impact on corporate green governance. Therefore, even after accounting for potential endogeneity issues, the conclusions drawn in the preceding analysis remain robust.

Table 5. Robustness Tests

	(1)	(2)	(3)	(4)	(5)
	GGP	GGP	CR	GGP	GGP
L.CR	0.067***				
	(0.012)				
CR1		0.044***			
		(0.004)			
CR_Ind			0.956***		
			(0.09)		
CR				0.085***	0.067***
				(0.018)	(0.010)
Size	0.027***	0.024***	0.034***	0.028***	0.028***
	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)
Age	-0.008	-0.005	-0.008***	-0.006	-0.004
	(0.006)	(0.005)	(0.003)	(0.005)	(0.005)
Bm	0.033	0.049**	0.043***	0.052**	0.043*
	(0.026)	(0.023)	(0.013)	(0.023)	(0.024)
Fixed	-0.043	-0.032	0.181***	-0.033	-0.037
	(0.028)	(0.025)	(0.014)	(0.025)	(0.025)
Roa	0.101**	0.120***	-0.018	0.110***	0.124***
	(0.048)	(0.042)	0.023	(0.042)	(0.045)
Lev	0.061**	0.069***	0.113***	0.073***	0.066***
	(0.027)	(0.024)	(0.013)	(0.024)	(0.025)
Own	-0.003	-0.016	-0.085***	-0.018	-0.006
	(0.025)	(0.022)	(0.012)	(0.022)	(0.022)
Dual	-0.021***	-0.025***	0.006*	-0.025***	-0.022***
	(0.007)	(0.006)	(0.004)	(0.006)	(0.007)
Board	-0.031	-0.033	-0.048***	-0.034	-0.035
	(0.025)	(0.022)	(0.012)	(0.022)	(0.022)
_cons	0.102	-0.020			0.078
	(0.113)	(0.099)			(0.101)
Year	yes	yes	yes	yes	yes
Industry	yes	yes	yes	yes	yes
N	16325	21440	21440	21440	20898
r2_a	0.127	0.130	0.325	0.010	0.124
Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$					

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5. Further Analysis

5.1. Impact Mechanism Test

The theoretical analysis presented in this study posits that climate risk promotes corporate green governance via two complementary pathways: enhancing green innovation and improving the quality of environmental information disclosure. Table 6 reports the regression results supporting these mechanisms. Columns (1) and (2) show that climate risk (CR) significantly enhances green innovation (GI), which in turn promotes green governance performance (GGP). Similarly, Columns (3) and (4) indicate that climate risk (CR) improves environmental information disclosure quality (EID), which subsequently promotes green governance performance (GGP).Climate risk motivates firms to renew strategic resources and build capabilities via green innovation, prompting the establishment of more systematic and agile green governance frameworks to manage these resources effectively. This process facilitates a transition from passive risk mitigation to proactive green transformation. Rising climate risk also intensifies external stakeholders' demand for corporate environmental disclosures, generating sustained oversight pressure that compels firms to continuously enhance institutional foundations, management processes, and operational efficiency in green governance. Collectively, these findings validate that climate risk promotes corporate green governance through the dual pathways of green innovation and environmental information disclosure, providing empirical support for Hypothesis 2.

Table 6. Results of Mechanism Test

	(1)	(2)	(3)	(4)
	GI	GGP	Eid	GGP
CR	0.697***	0.058***	0.150***	0.053***
	(0.023)	(0.010)	(0.017)	(0.010)
GI		0.014***		
		(0.003)		
Eid				0.091***
				(0.004)
Size	0.540***	0.022***	0.234***	0.008**
	(0.007)	(0.004)	(0.005)	(0.003)
Age	0.012	-0.006	-0.022***	-0.004
	(0.010)	(0.005)	(0.007)	(0.005)
Bm	-0.119**	0.055**	-0.136***	0.065***
	(0.053)	(0.023)	(0.038)	(0.023)
Fixed	-0.535***	-0.022	0.645***	-0.087***
	(0.057)	(0.025)	(0.040)	(0.025)
Roa	-0.303***	0.114***	0.246***	0.087**
	(0.097)	(0.042)	(0.069)	(0.042)
Lev	-0.020	0.076***	-0.208***	0.095***
	(0.055)	(0.024)	(0.039)	(0.024)
Own	-0.059	-0.019	0.259***	-0.043**
	(0.051)	(0.022)	(0.036)	(0.022)
Dual	0.021	-0.026***	-0.079***	-0.018***
	(0.015)	(0.006)	(0.011)	(0.006)
Board	0.091*	-0.037*	-0.180***	-0.019
	(0.050)	(0.022)	(0.036)	(0.022)
_cons	-11.404***	0.213**	-2.753***	0.308***
	(0.228)	(0.105)	(0.163)	(0.099)
Year	yes	yes	yes	yes
Industry	yes	yes	yes	yes
N	21440	21440	21440	21440
r2_a	0.482	0.128	0.424	0.147
Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$				

5.2. Heterogeneity Test

To investigate whether the impact of climate risk on corporate green governance varies according to

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firm-specific characteristics, this study conducts a subgroup regression analysis based on firms' levels of artificial intelligence (AI) adoption and internal control quality. Specifically, AI adoption is quantified using a word frequency index derived from annual report text analysis and categorized into High-AI and Low-AI groups using the sample median as the cutoff. Internal control quality is assessed via the Dibo Internal Control Index, with firms classified into High-IC and Low-IC groups according to the sample median. Table 7 reports the subgroup regression results. Columns (1) and (2) reveal that firms with higher AI adoption levels exhibit larger coefficients for the effect of climate risk on green governance compared to lower-AI firms, indicating a stronger moderating effect of AI on the climate risk–green governance relationship. Similarly, Columns (3) and (4) indicate that firms with higher internal control quality experience a stronger positive effect of climate risk on green governance than firms with lower internal control quality.

These findings suggest that advanced AI technologies improve environmental risk identification, analysis, and decision-making, while robust internal control mechanisms offer a reliable institutional foundation and operational safeguards, thereby significantly enhancing firms' governance effectiveness in responding to climate challenges. Consequently, policymakers and senior managers should consider firm-specific heterogeneity in governance capabilities and technological adoption when designing and implementing climate-related regulations. By encouraging firms to strengthen internal management quality and advance digital transformation, climate pressures can be more effectively harnessed as intrinsic drivers of green development.

Table 7. Results of Heterogeneity Test

	(1)	(2)	(3)	(4)
	High-AI	Low-AI	High-IC	Low-IC
CR	0.084***	0.051***	0.073***	0.062***
	(0.015)	(0.014)	(0.015)	(0.014)
Size	0.020***	0.037***	0.025***	0.030***
	(0.005)	(0.004)	(0.004)	(0.005)
Age	-0.002	-0.011*	0.001	-0.010
	(0.007)	(0.006)	(0.006)	(0.007)
Bm	0.167***	-0.038	0.111***	0.025
	(0.036)	(0.031)	(0.033)	(0.034)
Fixed	-0.036	-0.020	-0.003	-0.046
	(0.040)	(0.032)	(0.036)	(0.034)
Roa	0.158**	0.055	0.241***	-0.000
	(0.062)	(0.058)	(0.082)	(0.052)
Lev	0.207***	-0.033	0.129***	0.045
	(0.035)	(0.033)	(0.036)	(0.033)
Own	-0.030	-0.024	-0.026	-0.019
	(0.033)	(0.030)	(0.031)	(0.031)
Dual	-0.028***	-0.020**	-0.016*	-0.033***
	(0.009)	(0.009)	(0.009)	(0.009)
Board	-0.088***	0.014	-0.019	-0.048
	(0.032)	(0.030)	(0.031)	(0.031)
_cons	0.356**	-0.210	0.018	0.106
	(0.147)	(0.136)	(0.138)	(0.149)
Industry	yes	yes	yes	yes
Year	yes	yes	yes	yes
N	9670	11768	10733	10707
r2_a	0.111	0.151	0.116	0.141
Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$				

6. Discussion

This study systematically investigates the mechanisms through which climate risk influences corporate green governance, integrating perspectives from risk aversion and institutional pressure theories. The analysis demonstrates that climate risk enhances green governance through two complementary pathways: green innovation and environmental information disclosure, while highlighting the reinforcing roles of internal controls and AI adoption. While previous studies have

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examined the "double-edged sword" effects of climate risk on corporate economic outcomes—such as heightened financing constraints[8], stock price volatility[9], and enhanced ESG performance[12]—these investigations have predominantly focused on financial or disclosure outcomes, neglecting the transmission of such effects to corporate governance structures. Although certain studies suggest that climate risks can stimulate green technological innovation[13] or corporate social responsibility fulfillment[15], systematic explanations of the underlying governance mechanisms remain scarce. This study incorporates climate risk into a green governance analytical framework, demonstrating that it operates through dual channels—"resource restructuring" (green innovation) and "signaling" (environmental information disclosure)—thereby compelling firms to transform green governance from an optional management practice into a strategic organizational imperative. This approach addresses a critical gap in the literature by elucidating the "risk-behavior-governance" linkage mechanism.

This study advances the literature in three principal ways. First, it develops an integrated "risk-behavior-governance" model, offering a novel framework for understanding corporate strategic responses to climate pressures. Second, it clarifies the transmission mechanisms, demonstrating that green innovation establishes the resource and capability base for governance, whereas environmental information disclosure constitutes an external oversight loop, collectively reinforcing green governance effectiveness and addressing the "black box" problem in the literature[33,36]. Third, it incorporates a heterogeneity perspective, showing that internal controls and AI adoption amplify the impact of climate risk through institutional safeguards and technological empowerment. These findings align with emerging research on digital transformation[20] and governance effectiveness[27], further elucidating the boundary conditions of climate risk effects.

7. Conclusions and Policy Implications

7.1. Conclusions

This study empirically investigates the impact of climate risk on corporate green governance and the underlying mechanisms, utilizing data from Chinese A-share listed companies spanning 2011 to 2023. The findings are threefold. First, climate risk significantly promotes corporate green governance, and this result remains robust following a series of stability and endogeneity tests. Second, mechanism analysis demonstrates that climate risk significantly promotes green governance through two complementary pathways: enhancing green innovation and improving the quality of environmental information disclosure. Specifically, climate risk stimulates green technological innovation, creating new resource and capability bases that enable firms to tackle environmental challenges, thereby necessitating upgrades to governance structures. Simultaneously, by enhancing the quality of environmental information disclosure, climate risk exploits signaling effects and external oversight pressures, compelling firms to implement verifiable internal management systems and transparent processes, thereby systematically improving green governance effectiveness. Third, heterogeneity analysis indicates that the catalytic effect of climate risk on green governance is stronger in firms with advanced AI adoption and high-quality internal controls. This suggests that risk identification and management capabilities enabled by advanced technologies, combined with institutional safeguards provided by robust internal governance, jointly enhance the effectiveness of transforming climate risks into drivers of green governance. This underscores the boundary role of firms' intrinsic technological and institutional capacities in shaping the effectiveness of climate risk-driven green governance.

7.2. Management Implications

Based on these findings, several management implications can be drawn:

For corporate managers, it is recommended to establish a climate-risk-oriented governance system by integrating climate risks into core strategic frameworks and implementing dynamic green governance mechanisms. First, firms should enhance climate risk identification and assessment capabilities by employing digital tools for real-time monitoring of physical risks and by tracking transition risks through systematic policy scanning. Second, firms should promote the synergistic evolution of green innovation and governance structures by establishing dedicated green R&D funds to support breakthroughs in low-carbon technologies. Simultaneously, firms should optimize organizational structures by establishing climate committees under the board of directors and integrating carbon reduction targets into executive performance evaluations. Additionally, firms should strengthen climate information disclosure management by not only reporting climate-related financial

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information in accordance with TCFD recommendations, but also implementing internal data verification mechanisms to mitigate capital cost pressures arising from information asymmetry.

For policymakers, governments should guide corporate green transformation through multidimensional policy instruments. First, governments should refine climate risk classification and management policies by setting phased emission reduction quotas for high-carbon industries and providing preferential approval channels for renewable energy enterprises. Second, governments should strengthen mandatory disclosure requirements and provide technical support by mandating climate risk governance disclosures in listing rules and developing a unified national carbon accounting platform to reduce compliance costs for SMEs. Third, governments should implement differentiated regional policies by prioritizing incentives for demonstration projects that integrate AI with green technologies and by supporting renewable energy infrastructure through ecological compensation mechanisms to prevent regional development disparities associated with uniform policies.

For industry associations and intermediaries, these organizations and financial institutions should function as pivotal hubs. Industry associations should establish sector-level climate governance standards, develop enterprise climate risk rating systems, and award certification labels to leading companies to foster competitive peer pressure. Financial institutions should innovate climate finance instruments, enhance the weighting of climate governance factors, and channel capital flows toward firms with advanced green governance practices. Additionally, third-party certification bodies should conduct quality audits of climate information disclosures, providing credible market benchmarks through annual rating reports to mitigate greenwashing risks.

7.3. Research Limitations and Future Prospects

This study has certain limitations. First, it focuses solely on Chinese A-share listed companies, excluding unlisted firms and other economies, leaving the universality of its conclusions to be verified. Future research could expand to cross-industry samples and compare heterogeneity across different institutional contexts. Second, climate risk measurement relies on text analysis; future work could integrate multiple rating systems to enhance robustness. Finally, this study concentrates on two mechanisms—green innovation and environmental disclosure—without exploring other pathways. Future research could deepen the analysis by incorporating organizational behavior or supply chain dimensions.

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