

Climate Policy Uncertainty, Strategic Corporate Responses and Environmental Governance Performance

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Abstract. Against the backdrop of continuous progress toward the carbon peaking and carbon neutrality goals, climate policy uncertainty has become a critical external factor shaping enterprises' green governance decisions. Based on data of Shanghai and Shenzhen A-share listed companies in China from 2010 to 2023, this paper examines the impact of climate policy uncertainty on corporate green governance performance and its underlying mechanisms. The study finds that climate policy uncertainty significantly reduces corporate green governance performance, and this conclusion remains valid after a series of robustness tests. Mechanism analysis shows that climate policy uncertainty first strengthens enterprises' perception of policy fluctuations, and then triggers strategic response behaviors. In terms of environmental information disclosure, enterprises tend to increase textual environmental disclosure without corresponding improvement in actual environmental governance disclosure. In terms of green innovation, climate policy uncertainty significantly suppresses applications for green invention patents but has no significant effect on green utility model patents, indicating that it mainly crowds out substantive green innovation featuring high investment and long cycles. From the perspective of strategic response, this paper reveals the micro mechanism through which climate policy uncertainty affects corporate green governance performance, and provides empirical evidence for stabilizing climate policy expectations, standardizing environmental information disclosure and guiding enterprises to conduct substantive green innovation.

Keywords: Climate Policy Uncertainty, Green Governance Performance, Strategic Response, Environmental Information Disclosure, Green Innovation

1. Introduction

Achieving the carbon peaking and carbon neutrality goals is a major strategic decision made by the central government in consideration of both domestic and international situations. In recent years, China's climate governance system has been continuously improved. Policy documents including the *Action Plan for Carbon Dioxide Peaking Before 2030* and the *Guidelines on Fully and Faithfully Applying the New Development Philosophy to Achieve Carbon Peaking and Carbon Neutrality* have been rolled out successively. Institutional arrangements such as low-carbon pilots, the development of carbon emissions trading markets, green finance reform, and the transition from the "dual control of energy consumption" to the "dual control of carbon emissions" have been implemented steadily,

providing clear institutional guidance for the green transformation of enterprises [1]. However, the intensive introduction of climate policies and their differentiated implementation across localities have also brought instability to policy expectations. The dynamic adjustment of climate policies in terms of implementation timing, enforcement intensity, subsidy orientation and regulatory boundaries makes it difficult for enterprises to accurately forecast the costs and benefits of green governance in the future [2]. In particular, green governance involves long-term investments in equipment upgrading, process transformation, emission reduction management and green R&D, which are highly asset-specific and irreversible. When policy signals are ambiguous or fluctuate frequently, enterprises may choose to wait, delay or scale back green initiatives. More notably, when faced with uncertainty, enterprises may not directly cut all green activities. Instead, they may respond strategically through means such as environmental information disclosure and green patent applications, creating a gap between stated commitments and actual actions. Therefore, how climate policy uncertainty affects corporate green governance and what response strategies enterprises will adopt are key issues for understanding corporate green transformation behavior under the "dual carbon" agenda.

Accordingly, based on data of A-share listed companies from 2010 to 2023, this paper takes the urban climate policy uncertainty index as the core variable to empirically test its impact on corporate green governance performance and the strategic response mechanism. The study finds that climate policy uncertainty significantly inhibits corporate green governance performance. Its functioning mechanism lies in strengthening enterprises' perception of uncertainty, inducing strategic behaviors that prioritize textual disclosure over substantive governance, and crowding out high-investment green invention patents. This paper provides empirical evidence for stabilizing climate policy expectations and guiding enterprises toward substantive green transformation.

The marginal contributions of this paper are mainly as follows. In terms of research scope, this paper incorporates climate policy uncertainty into the analytical framework of corporate green governance performance, expanding the research on the microeconomic consequences of climate policy uncertainty. Different from existing literature that mainly focuses on investment, financing or green innovation, this paper further examines its comprehensive impact on corporate green governance performance. In terms of mechanism, this paper highlights enterprises' strategic response behaviors, distinguishes between textual environmental disclosure and substantive environmental governance disclosure, as well as strategic green innovation and substantive green innovation, and reveals the behavioral bias induced by climate policy uncertainty: overemphasis on textual disclosure, neglect of substantive governance, and reduction of substantive R&D.

2. Literature review and research hypotheses

2.1. Literature review

Climate policy uncertainty alters enterprises' judgments on future regulatory intensity, compliance costs and green investment returns, and shapes enterprises' resource allocation. Gowrisankaran et al. found that uncertainty in environmental policy enforcement raises the value of waiting for enterprises and delays their adoption of emission reduction technologies and exit decisions [3]. Gavrilidis et al. pointed out that climate policy uncertainty dampens corporate investment and R&D, and enterprises with higher climate exposure suffer more pronounced impacts [4]. Domestic studies have also found that climate policy uncertainty widens the credit spread of corporate bonds and weakens enterprises' external financing capacity [3]. Yu Bo and Yu Chengzhen further explained from both the credit supply side and enterprise demand side that climate policy uncertainty reduces

enterprises' access to credit [5]. It can be seen that climate policy uncertainty is not only a change in the macro policy environment, but also affects micro enterprise decisions through channels of investment, financing and risk expectations.

2.2. Theoretical analysis and research hypotheses

2.2.1. Direct impact of climate policy uncertainty on green governance performance

Corporate green governance performance depends on stable policy expectations and sustained resource input. Green governance usually involves environmental protection equipment renewal, clean production transformation, emission reduction management system construction and green technology R&D, all of which are highly specific and long-term investments. When there is high uncertainty about future policy direction, enforcement intensity and support measures, enterprises can hardly accurately evaluate the costs and benefits of green governance investment. According to the real option theory, when investment is irreversible and future returns are uncertain, enterprises tend to postpone investment to preserve the option value of waiting. The study by Gowrisankaran et al. also confirms that uncertainty in environmental policy enforcement delays enterprises' adoption of emission reduction technologies and exit decisions [3].

Climate policy uncertainty also constrains corporate green governance through the financing environment. Green governance activities often require continuous financial support, while policy uncertainty heightens concerns among external investors and financial institutions about enterprises' future cash flow, compliance costs and transition risks. Wang Shun and Zhou Zejiang found that climate policy uncertainty significantly widens the credit spread of corporate bonds [6]. Yu Bo and Yu Chengzhen noted that uncertainty reduces enterprises' credit availability [5]. Rising financing costs and declining capital accessibility will narrow the room for enterprises' green governance investment, making enterprises more inclined to prioritize short-term operational stability.

Climate policy uncertainty also undermines the continuity of corporate green strategies. Green governance performance cannot be achieved through one-time investment; it requires continuous adjustments in technology, management and organization. When policy signals change frequently, enterprises can hardly form a stable green transformation roadmap, and their green governance practices are prone to wait-and-see attitudes, contraction or phased interruption. Wang Shun et al. found that climate policy uncertainty crowds out physical investment and green innovation investment, and traps enterprises in upgrading dilemmas [5]. Therefore, climate policy uncertainty may inhibit corporate green governance performance jointly through delayed investment, tightened financing and interrupted strategies. Accordingly, this paper proposes Hypothesis 1:

Hypothesis 1: Climate policy uncertainty significantly inhibits corporate green governance performance.

2.2.2. Climate policy uncertainty and enterprises' uncertainty perception

As an exogenous institutional shock, city-level climate policy uncertainty (CCPU) does not directly affect enterprise decisions. It can substantially drive adjustments in green governance behaviors only after being filtered by the management's subjective cognition and transformed into internally perceivable policy fluctuation expectations [7]. Climate policies not only impose explicit requirements such as current environmental compliance costs and emission constraints on enterprises, but also profoundly reshape enterprises' long-term judgments on future green investment returns, regulatory boundaries and operational risks through channels such as carbon pricing

mechanisms, green technology standards, environmental subsidy policies and low-carbon market access [8].

Marotta et al. constructed the CPU-Concern index based on media texts and confirmed that the commitment strength and credibility of climate policies are core factors shaping market participants' perception: policy disputes and insufficient communication significantly amplify market uncertainty perception, while formal policy approval and on-the-ground implementation effectively reduce expectation volatility [8]. Cassidy further pointed out that political processes and policy announcements continuously send signals about future climate policy intensity to the market, and enterprise management will reassess climate transition risks and the feasibility of green decisions based on the stability of policy signals [9]. When city-level climate policy signals fluctuate frequently and implementation standards are ambiguous, enterprises can hardly form stable policy expectations, and the management's uncertainty about future regulatory rules, carbon costs and technical requirements rises sharply, thus strengthening overall corporate perception of uncertainty.

From the perspective of enterprise decision-making, such perceptual change directly alters the decision baseline for green governance investment. When policy expectations are stable, enterprises can arrange environmental governance and green innovation according to established plans; when policy expectations are unstable, enterprises will treat green governance as a high-risk, long-payback and uncertain-return investment project, and adjust their resource allocation accordingly [1]. Macro empirical evidence from Gavrilidis et al. also shows that climate policy uncertainty shocks directly reduce enterprises' willingness to invest and conduct R&D, and this effect is transmitted through aggravated expectation volatility [4]. Therefore, external city-level climate policy uncertainty will be translated into internal perception of policy fluctuations within enterprises. Accordingly, this paper proposes Hypothesis 2:

Hypothesis 2: Climate policy uncertainty significantly enhances enterprises' perception of policy fluctuations and strengthens their uncertainty expectations.

2.2.3. Climate policy uncertainty and strategic environmental information disclosure behavior

Faced with climate policy uncertainty, enterprises may not immediately increase substantive green governance investment. Instead, they may prioritize environmental information disclosure, which costs less and is more visible. Environmental information disclosure can send green signals to the government, investors and the public, and alleviate external stakeholders' concerns about enterprises' climate risks and compliance risks. He Taiming et al. found that divergent ESG ratings prompt listed companies to increase voluntary information disclosure [10]. Yang Yongliang et al. also found that when climate policy uncertainty rises, enterprises increase environmental information disclosure to adapt to policy changes [11].

However, there is a notable gap between textual disclosure and substantive governance in environmental information disclosure, which prevents it from being effectively translated into green governance performance. Sun Xiaohua et al. constructed a carbon information disclosure catering index and confirmed that enterprises cater to external pressure through exaggerated rhetorical modification, without support from real emission reduction actions or environmental protection investment [12]. Kimbrough et al. further noted that an overly positive tone in ESG disclosure reduces report credibility and can hardly be recognized by the market as substantive governance outcomes [13]. Gong Ning et al. divided corporate disclosure motives into legitimacy defense and signal transmission. Under climate policy uncertainty, underperforming enterprises mostly adopt defensive disclosure, only adding textual statements such as green strategies and environmental philosophies without substantive governance investment [14]. A market reaction study by Sun Jiakui

et al. also shows that low-quality carbon disclosure that only reports positive outcomes not only fails to improve governance performance, but also triggers negative market feedback [15].

Therefore, climate policy uncertainty may drive enterprises to increase textual environmental information disclosure, but does not necessarily bring synchronous improvement in substantive environmental governance actions. This divergence reflects enterprises' strategic disclosure behavior under policy uncertainty: responding to external pressure at low cost while postponing high-cost governance investment. Accordingly, this paper proposes Hypothesis 3:

Hypothesis 3: Climate policy uncertainty induces strategic response in environmental information disclosure, manifested as increased textual environmental disclosure without synchronous improvement in substantive environmental governance disclosure.

2.2.4. Climate policy uncertainty and strategic R&D in green innovation

Green innovation is a critical foundation for enterprises to improve green governance performance. According to innovation quality and decision logic, green innovation can be divided into substantive green innovation and strategic green innovation, which differ significantly in their sensitivity to policy uncertainty.

Substantive green innovation features long R&D cycles, large capital investment, and high dependence of technology commercialization and market returns on policy certainty. When climate policy uncertainty rises, management worries that policy changes may render green technology routes obsolete and make investments unrecoverable, and thus cut such irreversible high-risk R&D spending. From a real option perspective, Gowrisankaran et al. confirmed that policy uncertainty increases the waiting value of green investment, and enterprises tend to delay the adoption of emission reduction technologies and green R&D. Wang Shun et al. also found that climate policy uncertainty crowds out green innovation investment, exacerbates misallocation of physical resources, and further suppresses substantive innovation input. In contrast, green utility model patents have shorter R&D cycles and lower technical thresholds, serving more as image-building tools. Even if enterprises scale back long-term green R&D in an uncertain environment, they may not reduce such short-cycle innovation activities simultaneously. Wang Yonggui and Li Xia found that corporate green innovation can be categorized into strategic and substantive types, which respond differently to policy incentives [16]. Tao Feng et al. also showed that environmental policy pressure may drive growth in the number of green patents, but does not necessarily improve innovation quality [17]. Du Yang further found that urban climate policy uncertainty exerts a positive U-shaped effect on the sustainability of green technology innovation, and excessive uncertainty will completely suppress long-term investment in substantive innovation [18].

Such structural changes in innovation will further weaken corporate green governance performance. Substantive green innovation improves corporate green governance by upgrading processes, reducing emissions and enhancing resource utilization efficiency, and is a key source of long-term governance capacity. Strategic green innovation, while helpful for improving enterprises' short-term green image, can hardly replace the role of high-quality green R&D in actual governance performance. Therefore, climate policy uncertainty is more likely to suppress enterprises' substantive green innovation and erode the long-term technological foundation for green governance performance improvement.

Based on the above analysis, Hypothesis 4 is proposed:

Hypothesis 4: Climate policy uncertainty significantly inhibits enterprises' substantive green innovation and has a weaker impact on strategic green innovation, thus weakening the long-term foundation for improving corporate green governance performance.

3. Research design

3.1. Data sources

This paper selects Shanghai and Shenzhen A-share listed companies in China from 2010 to 2023 as the research sample. Among them, basic enterprise information and financial data are from the CSMAR Database; city-level climate policy uncertainty is from the China Climate Policy Uncertainty Index developed by Ma; corporate green governance performance data is obtained through manual sorting combined with the CSMAR Database and the CNRDS Database. The samples are filtered as follows: ① Exclude samples from the financial industry; ② Exclude samples of enterprises with abnormal operating status such as ST and *ST; ③ Exclude samples with severely missing core variables; ④ Winsorize all continuous variables at the 1% and 99% percentiles by year to mitigate the impact of extreme values on empirical results. A total of 24,786 observations are obtained.

3.2. Model specification

To test the impact of climate policy uncertainty on corporate green governance performance, this paper constructs a two-way fixed effects model. The specific model is specified as follows:

$$GGP_{it} = \beta_0 + \beta_1 CPU_{city_{it}} + \gamma X_{it} + \lambda_i + \mu_t + \varepsilon_{it}$$

Where subscripts i and t denote enterprise and year respectively. $CPU_{city_{it}}$ represents the city-level climate policy uncertainty of the city where enterprise i is located in year t , and GGP_{it} denotes the green governance performance of enterprise i in year t . Vector X represents enterprise-level control variables. λ_i and μ_t are enterprise fixed effects and year fixed effects respectively, used to control for individual enterprise heterogeneity and macro time trends. ε_{it} is the random disturbance term. Cluster-robust standard errors clustered at the city level are used in regressions to control for correlation among enterprises in the same city.

3.3. Variable description

(1) Core explanatory variable: Climate policy uncertainty (CPU_city)

This paper adopts the climate policy uncertainty index at China's prefecture-level city level constructed by Ma et al. [7]. Based on deep learning algorithms and careful manual auditing, the index is calculated through text analysis of climate policy-related content in over 1.7 million articles from 6 major Chinese newspapers including *People's Daily* and *Guangming Daily*. This paper computes the arithmetic mean of the monthly uncertainty index for each prefecture-level city over the 12 months of the year to derive the annual city-level climate policy uncertainty index as the core explanatory variable. A higher value indicates greater climate policy uncertainty in the city.

(2) Explained variable: Corporate green governance performance (GGP)

Referring to the method of Zhang Yun et al. [19], this paper measures green governance performance using the *Janis-Fadner* coefficient based on positive and negative scores of a company's participation in green governance. GGP ranges from -1 to 1, and a larger value indicates better green governance performance of the enterprise.

(3) Control variables

This paper controls for enterprise-level factors that may affect green governance performance, including: ① Enterprise financial characteristics: firm size (*Size*), asset-liability ratio (*Lev*), return on assets (*Roa*), operating cash flow (*Cfo*), total asset turnover (*Tat*); ② Corporate governance structure: board size (*Board*), equity balance (*Balance*), shareholding ratio of the largest shareholder (*Top1*), proportion of independent directors (*Indboard*). As shown in the descriptive statistics in Table 1, the mean, standard deviation and value range of each control variable are within reasonable ranges, with no obvious outliers.

Table 1. Descriptive statistics

<i>Variable</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>
<i>GGP</i>	24786	0.4915	0.5615	-1.0000	1.0000
<i>CPU_city</i>	24786	1.6287	0.6006	0.0000	4.0568
<i>Size</i>	24786	22.1691	1.2115	19.0952	26.4143
<i>Lev</i>	24786	0.4146	0.2008	0.0191	1.0564
<i>Roa</i>	24786	0.0370	0.0659	-0.4471	0.2331
<i>Cfo</i>	24786	0.0509	0.0670	-0.2115	0.2724
<i>Tat</i>	24786	0.6080	0.3928	0.0688	3.2902
<i>Board</i>	24786	2.1082	0.1945	1.6094	2.8332
<i>Balance</i>	24786	0.7757	0.6149	0.0147	3.0659
<i>Top1</i>	24786	0.3329	0.1435	0.0836	0.7702
<i>Indboard</i>	24786	0.3772	0.0532	0.2500	0.5714

4. Empirical analysis

4.1. Baseline regression

Table 2 reports the estimation results of the baseline regression. Column (1) presents the regression result without any control variables or fixed effects, which preliminarily shows that climate policy uncertainty has a significant inhibitory effect on corporate green governance performance. Columns (2) to (4) gradually add enterprise-level control variables, year fixed effects and enterprise individual fixed effects. The results show that the coefficient of *CPU_city* remains significantly negative throughout. As the omitted variable problem is alleviated, the absolute value of the estimated coefficient decreases, but the regression results remain robust. This indicates that rising climate policy uncertainty significantly reduces enterprises' willingness and input in green governance, and suppresses corporate green governance performance. Hypothesis 1 is verified: climate policy uncertainty significantly inhibits corporate green governance performance.

Table 2. Baseline regression

	(1)	(2)	(3)	(4)
Variables	<i>GGP</i>	<i>GGP</i>	<i>GGP</i>	<i>GGP</i>
<i>CPU_city</i>	-0.1177*** (0.0096)	-0.1043*** (0.0088)	-0.0727*** (0.0098)	-0.0371*** (0.0116)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	No	No	Yes	Yes

Table 2. (continued)

Enterprise fixed effects	No	No	No	Yes
<i>Observation</i>	24786	24786	24786	24786
<i>R²_adjusted</i>	0.0158	0.0484	0.0615	0.4044

Note: *, ** and *** represent significance at the 10%, 5% and 1% levels respectively. Cluster-robust standard errors clustered at the city level are in parentheses.

4.2. Endogeneity treatment

To alleviate endogeneity problems such as omitted variables, measurement error and reverse causality that may exist in the baseline regression and ensure the robustness of the conclusion, this paper adopts the two-stage least squares (2SLS) method for endogeneity treatment. Following the research approach of Yang Yongliang et al. [11], average surface temperature and population density are selected as instrumental variables. In terms of relevance: average surface temperature directly reflects the degree of climate warming. Rising temperatures prompt the government to introduce more frequent and stricter climate response policies, thus increasing climate policy uncertainty. In areas with high population density, people are more aware of climate warming, and concentrated resource consumption and economic activities are prone to trigger extreme weather events, which in turn push the government to adjust climate policies and also raise climate policy uncertainty. In terms of exogeneity: neither average surface temperature nor population density directly affects corporate green governance performance, satisfying the exogeneity condition. Theoretically, both instrumental variables meet the two requirements of relevance and exogeneity.

Accordingly, this paper uses the product of average surface temperature and population density from the IPCC Sixth Assessment Report database as the instrumental variable. The instrumental variable regression results are shown in Table 3. The first-stage F-statistic is 163.613, which is above the empirical threshold of 10, rejecting the weak instrumental variable hypothesis. In addition, the LM statistic test shows no under-identification problem for the instrumental variable. Both the Kleibergen-Paap rk Wald F and Cragg-Donald Wald F statistics are greater than the empirical critical value of 10, rejecting the weak instrument problem. The second-stage regression results show that the coefficient of *CPU_city* is significantly negative at the 1% level, consistent with the baseline regression conclusion. This indicates that after controlling for endogeneity, the inhibitory effect of climate policy uncertainty on corporate green governance performance remains robust..

Table 3. Instrumental variable method

	(1) First stage	(2) Second stage
Variables	<i>CPU_city</i>	<i>GGP</i>
<i>IV</i>	0.0011*** (0.0003)	
<i>CPU_city</i>		-0.1730** (0.0860)
Control variables	Yes	Yes

Table 3. (continued)

Year fixed effects	Yes	Yes
Enterprise fixed effects	Yes	Yes
<i>Kleibergen-Paap rk LM</i>		184.260***
<i>Kleibergen-Paap rk Wald F</i>		163.613
<i>Cragg-Donald Wald F</i>		139.538
<i>Observation</i>	24786	24786

Note: *, ** and *** represent significance at the 10%, 5% and 1% levels respectively. Cluster-robust standard errors clustered at the city level are in parentheses.

4.3. Robustness checks

To further verify the reliability of the research conclusion, this paper conducts robustness checks from three aspects: replacing the explained variable, replacing the core explanatory variable, and adjusting model specification. The results are presented in Table 4.

4.3.1. Replacing the explained variable

To address potential measurement bias in the explained variable, this paper replaces the measure of corporate green governance performance with the environmental dimension score (*EnvironScore*) from the Huazheng ESG Rating System as the alternative explained variable. This indicator comprehensively evaluates enterprises' green performance from multiple dimensions such as environmental governance and fulfillment of environmental responsibilities, and can more fully reflect the actual outcomes of corporate green governance. The results in column (1) of Table 4 show that the coefficient of the core explanatory variable, city-level climate policy uncertainty, is significantly negative, fully consistent with the sign and significance of the baseline regression results. This indicates that after replacing the explained variable, the inhibitory effect of climate policy uncertainty on corporate green governance performance still holds, and the baseline conclusion remains essentially unchanged.

4.3.2. Replacing the explanatory variable

Considering that China's climate policies are usually designed, formulated and adjusted at the national level and then implemented by provincial, municipal and even county-level governments in light of local conditions, policy trends and implementation attitudes at the provincial level may largely influence climate policy uncertainty at subsequent administrative levels. To test the robustness of the measurement of the core explanatory variable, this paper replaces the measurement level of climate policy uncertainty from the city level to the provincial level (*CPU_prov*), and re-runs the regression using the provincial climate policy uncertainty index. The results in column (2) of Table 4 show that the coefficient of provincial climate policy uncertainty is significantly negative, consistent with the baseline regression results. This indicates that both city-level and provincial climate policy uncertainty exert significant inhibitory effects on corporate green governance performance, and the core conclusion is not affected by how the core variable is measured.

4.3.3. Adjusting model specification

To address potential model specification bias, this paper adjusts the baseline model across multiple dimensions of fixed effects: ① Control for industry and year fixed effects to absorb heterogeneous shocks across industries over time; ② Control for high-dimensional fixed effects of enterprise, city and year to further rule out interference from time-varying macro factors at the city level. The results in columns (3) and (4) of Table 4 show that after adjusting the fixed effect specification, the coefficient of urban climate policy uncertainty remains significantly negative, consistent with the baseline regression results.

Table 4. Robustness checks

	(1) Huazheng score	(2) Provincial CPU	(3) Industry fixed effects	(4) City fixed effects
Variables	<i>EnvironScore</i>	<i>GGP</i>	<i>GGP</i>	<i>GGP</i>
<i>CPU_city</i>	-0.4091** (0.1587)		-0.0511*** (0.0108)	-0.0371*** (0.0108)
<i>CPU_prov</i>		-0.0536*** (0.0188)		
Control variables	Yes	Yes	Yes	Yes
Enterprise fixed effects	Yes	Yes	No	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	No	No	Yes	No
City fixed effects	No	No	No	Yes
<i>Observation</i>	24786	24786	24785	24785
<i>R²_adjusted</i>	0.4891	0.4045	0.1474	0.3975

Note: *, ** and *** represent significance at the 10%, 5% and 1% levels respectively. Cluster-robust standard errors clustered at the city level are in parentheses.

5. Mechanism analysis

5.1. Corporate expectation transmission mechanism

Rising climate policy uncertainty aggravates information asymmetry for enterprises regarding future policy orientation, compliance costs and market environment, strengthens enterprises' perception of climate policy fluctuations, forms stronger uncertainty expectations, and then affects enterprises' green governance decisions. To verify this transmission path, this paper constructs corporate climate policy uncertainty perception (*CPU_perception*) as the mechanism variable for testing. The construction of *CPU_perception* mainly draws on the method of Nie Huihua et al.: extract the Management's Discussion and Analysis (MD&A) section from listed companies' annual reports [20], perform word segmentation on a sentence basis; then identify sentences that contain both uncertainty-related words and climate policy-related words; finally calculate the ratio of the number of uncertainty words in such sentences to the total number of words in MD&A as the measure of enterprises' climate policy uncertainty perception. A larger value indicates a higher degree of enterprises' perception of climate policy uncertainty. The results in column (1) of Table 5 show that rising climate policy uncertainty significantly enhances enterprises' perception of climate policy fluctuations and strengthens their uncertainty expectations.

Table 5. Mechanism analysis

	(1) Uncertainty perception	(2) Textual disclosure	(3) Actual disclosure	(4) Strategic innovation	(5) Substantive innovation
Variables	<i>CPU_perception</i>	<i>CID_text</i>	<i>CID_actual</i>	<i>lnGreenUti</i>	<i>lnGreenInv</i>
<i>CPU_city</i>	0.0774*** (0.0254)	0.0065*** (0.0018)	0.0289 (0.0382)	-0.0075 (0.0088)	-0.0175** (0.0082)
Control variables	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Enterprise fixed effects	Yes	Yes	Yes	Yes	Yes
<i>Observation</i>	11489	24786	24786	24786	24786
<i>R²_adjusted</i>	0.3578	0.4392	0.6470	0.6384	0.6855

Note: *, ** and *** represent significance at the 10%, 5% and 1% levels respectively. Cluster-robust standard errors clustered at the city level are in parentheses.

5.2. Corporate strategic response mechanism

On the basis of forming uncertainty expectations, enterprises adjust their green governance investment through different strategic response behaviors. This paper further examines the strategic response paths from two dimensions: environmental information disclosure and green innovation.

5.2.1. Environmental information disclosure strategy

Faced with rising climate policy uncertainty, enterprises may adjust their environmental information disclosure practices to send signals and manage market expectations, resulting in differentiated performance between textual disclosure and actual actions. Columns (2) and (3) of Table 5 test the impact of climate policy uncertainty on enterprises' textual environmental disclosure (*CID_text*) and actual environmental governance disclosure (*CID_actual*) respectively. In column (2), the regression coefficient of *CPU_city* on *CID_text* is significantly positive, indicating that higher climate policy uncertainty leads enterprises to increase textual environmental information disclosure, so as to alleviate information asymmetry and stabilize market expectations by actively sending green governance signals. In column (3), the regression coefficient of *CPU_city* on *CID_actual* fails the significance test, indicating that enterprises do not simultaneously increase actual environmental governance actions. This presents a strategic feature of strengthened textual disclosure alongside lagged actual actions, reflecting that under policy uncertainty, enterprises prefer to respond to risks through low-cost signal transmission rather than substantive investment.

5.2.2. Adjustment of green innovation investment

Green innovation is the core support for enterprises to achieve long-term green governance performance. However, such activities feature high investment, high risk and long return cycles, and are highly sensitive to policy uncertainty. This paper further tests the impact of climate policy uncertainty on enterprises' applications for green utility model patents (*lnGreenUti*) and green invention patents (*lnGreenInv*). Columns (4) and (5) of Table 5 report the relevant results. In column (4), the regression coefficient of *CPU_city* on *lnGreenUti* is not statistically significant. In column

(5), the regression coefficient of *CPU_city* on *lnGreenInv* is significantly negative, indicating that rising climate policy uncertainty significantly inhibits enterprises' green invention patent applications and crowds out long-term green innovation investment. The main reason is that green invention patents have longer R&D cycles, higher investment and greater uncertainty, and are far more sensitive to policy fluctuations than utility model patents. When climate policy uncertainty rises, enterprises will prioritize cutting R&D investment in high-investment, high-risk invention patents to avoid R&D risks, thereby undermining enterprises' long-term green innovation capacity.

6. Research conclusions and policy implications

How climate policy uncertainty affects micro enterprises' green governance behavior is an important issue for coordinating climate governance and high-quality economic development under the "dual carbon" goals. Based on panel data of Shanghai and Shenzhen A-share listed companies in China from 2010 to 2023, this paper empirically tests the impact and mechanism of city-level climate policy uncertainty on corporate green governance performance. The core conclusions are as follows: ① City-level climate policy uncertainty has a significant inhibitory effect on corporate green governance performance. This conclusion remains robust after multiple robustness checks and using the instrumental variable method to alleviate endogeneity. ② Climate policy uncertainty inhibits corporate green governance performance through the corporate expectation transmission mechanism and the corporate strategic response mechanism. ③ Climate policy uncertainty significantly enhances enterprises' perception of policy fluctuations and strengthens uncertainty expectations, thus distorting enterprises' green governance decisions. Under uncertainty, enterprises exhibit a behavioral bias of emphasizing textual disclosure while neglecting substantive governance. Meanwhile, they significantly cut R&D investment in high-investment, high-risk green invention patents, which ultimately suppresses the improvement of green governance performance. Based on the above findings, this paper puts forward the following policy recommendations:

To reduce the impact of policy uncertainty, the government should build a stable and predictable climate policy system. In line with the overall requirements of advancing "dual carbon" work under national coordination, the government should strengthen the top-level design and continuity of climate policies, clarify the direction and roadmap of policy adjustment, and reduce expectation distortion caused by frequent policy changes. The government should also establish a forward-looking guidance and interpretation mechanism for climate policies to stabilize enterprises' green investment expectations. Finally, policy stability should be incorporated into local climate governance assessment to avoid one-size-fits-all approaches and short-term policy fluctuations, so as to provide a stable institutional environment for corporate green governance.

The government should also improve the regulatory framework for corporate green governance to standardize information disclosure and substantive actions. It is necessary to implement the CSRC's requirements on sustainable development information disclosure for listed companies, unify environmental information disclosure standards, distinguish between textual disclosure and substantive governance indicators, and strengthen regulatory constraints on "greenwashing" and "selective disclosure" behaviors. Promote the implementation of third-party verification for green governance information, improve the credibility of disclosed data, and guide enterprises to shift from strategic information disclosure to substantive environmental governance. Focus on supervising enterprises' green innovation investment, and introduce special incentives for high-quality innovation such as green invention patents to address the crowding-out effect on corporate green innovation under climate policy uncertainty.

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