

Climate Policy Uncertainty and Corporate Green Innovation Bubbles, Promote Or Inhibit?

Ziyuan Wang*, Xueying Meng

Business School, Shandong University of Technology, Zibo, 255000, China

*Corresponding Author: ZiyuanWang0819@163.com

Abstract

Climate policy uncertainty creates operational difficulties for enterprises while also containing potential opportunities. Corporate green innovation, serving as a crucial tool for environmental governance and sustainable development promotion, requires coordination between quality and quantity to ensure its practical effectiveness. The phenomenon of "quantity over quality" has become a verified reality in current corporate green innovation. By analyzing panel data from China's A-share listed companies during 2012-2023, this paper systematically examines the consequence of shocks from climate policy fluctuations on corporate green innovation bubbles while investigating its underlying mechanisms. The study finds that increased climate policy fluctuations significantly intensify corporate green innovation bubbles, whereas financial slack can effectively mitigate this phenomenon. This paper enriches the research system of climate policy uncertainty on corporate innovation behavior, and provides a solution for enterprises to alleviate green innovation bubbles in the face of climate policy fluctuations.

Keywords

Climate Policy Uncertainty; Corporate Green Innovation Bubbles; Financial Slack.

1. Introduction

The risks posed by climate change are posing severe threats to human society. From the Kyoto Protocol to the Paris Agreement, the international community has made a series of efforts and adjustments to better address climate change. Meanwhile, as a developing country that has made outstanding contributions to global economic development, China proposed the "Dual Carbon Goals" (peaking carbon emissions and achieving carbon neutrality) in 2020, along with a series of climate policies to respond to global climate governance needs and address the current complex and volatile climate environment. The economic competition among nations, developments in international politics, and the complexity of interactions between climatic-environmental changes and socio-economic transformations have resulted in significant volatility in climate policies. Enterprises, as key economic actors, find it challenging to adequately predict and prepare for the implementation of climate policies[1]. The growing uncertainty in climate policies compels enterprises to increase research and development investments and engage in green innovation[2], thereby reducing pollution and emissions to fulfill sustainability commitments[3]. However, to make substantive contributions to sustainable development, enterprises must ensure the quality of their green innovations. Consequently, corporate green innovation faces heightened requirements under increasing climate policy uncertainties. On one hand, climate policy uncertainty creates substantial unpredictability for corporate development. While compelled to adopt green innovation to meet policy requirements and maintain corporate image and reputation, enterprises struggle to allocate sufficient research and development investments funding due to operational risks

and challenges caused by policy uncertainty. This results in green innovations that merely meet quantitative targets[4], failing to ensure quality and exacerbating corporate green innovation bubbles. On the other hand, increased climate policy uncertainty can generate opportunities that drive technological breakthroughs. It compels enterprises to adopt long-term strategic planning, prioritizing resource allocation to projects with core competitiveness, promising market prospects, and alignment with future policy directions. At the same time, enterprises seek broader collaborations to ensure the applied value of green innovations, thereby securing long-term competitive advantages in the market.

This study analyzes panel data from Chinese A-share listed firms (2012-2023) to enhance and extend prior scholarship by investigating two pivotal issues. Initially, through empirical research, it validates the influence of climate policy uncertainty on the green innovation bubbles of enterprises. Subsequently, it elucidates the moderating role of financial slack amidst climate policy unpredictability on such innovation distortions. Analytical outcomes reveal that increased shocks from climate policy fluctuations will aggravate the green innovation bubbles of enterprises, while financial slack can mitigate the green innovation bubbles caused by the increase in the uncertainty of climate policy.

This paper investigates the consequence of climate policy uncertainty on the green innovation bubbles of enterprises, with the following marginal contributions: Firstly, in terms of the research perspective, most existing studies focus on the consequence of climate risks and climate policy fluctuations on enterprise green innovation. This research innovatively explores the impact of policy fluctuations under the backdrop of climate change on the green innovation bubbles of corporates, emphasizing the issue of "quantity over quality" in enterprise green innovation and filling the research gap regarding the consequence of policy uncertainty on enterprise technological innovation behavior. Secondly, in terms of the research content, this paper validates the mechanism path of financial slack in the consequence of shocks from climate policy fluctuations on the green innovation bubbles of enterprises, providing theoretical support for enterprises on how to avoid such bubbles when confronted with increased climate policy uncertainty.

2. Literature Review

The shocks induced by climate policy fluctuations exert profound impacts on corporate operations. The pace of technological advancement may outstrip the development of existing policy frameworks, creating a gap between regulatory systems and emerging technologies, thereby amplifying climate policy uncertainty[5]. On one hand, increased climate policy uncertainty negatively impacts corporate value and diminishes corporate economic performance[6],[7]. This occurs because heightened climate policy uncertainty reduces innovation investment, lowers risk tolerance[8], and hampers capacity for outward investment, market expansion, and new market development[9], ultimately placing enterprises at competitive disadvantages. However, some studies posit that climate policy uncertainty may generate new business opportunities and market demands, potentially stimulating enterprises to adapt their development and innovation strategies[10]. This strategic adaptation enables enterprises to seize opportunities for green innovation[11], thereby enhancing their competitiveness. Corporate green innovation contributes positively to environmental governance and sustainable development. With knowledge externalities[12][13], it facilitates corporate sustainability while generating supernormal profits[14] and improving financial performance.

However, realizing these positive effects requires enterprises to ensure substantial quality in green innovation[15]. From a macroeconomic perspective, financial risks deteriorate corporate financing environments, fostering low-quality green innovations[16]. From an internal

strategic decision-making viewpoint, as a speculative mindset stemming from external environmental pressures, managerial myopia severely compromises green innovation strategies, resulting in corporate green innovation bubbles[17],[18]. Concurrently, specific policies can enhance green innovation quality. For instance, China's green finance pilot zones demonstrably improve corporate green innovation quality[19]. Nevertheless, existing research has rarely examined the quality-quantity equilibrium in green innovation from a comprehensive policy volatility perspective.

In summary, while current studies predominantly analyze climate policy impacts on corporate green innovation, they inadequately address the quantity-quality imbalance under climate policy shocks. Furthermore, existing studies on corporate green innovation bubbles predominantly focus on isolated policies or unilateral perspectives, either from internal firm-level factors or external drivers. Therefore, this study empirically investigates climate policy uncertainty's impact on corporate green innovation bubbles, proposes mitigation strategies, and provides theoretical support for high-quality corporate development and social responsibility fulfillment.

3. Theoretical Analysis and Research Hypothesis

Firstly, the discrepancy between policy frameworks and emerging technologies drives climate policy volatility, resulting in inadequate regulatory oversight of novel technologies. This impedes the progression of technological innovation toward sustainability and practical applicability[5],[20]. Under such circumstances, according to signaling theory[21], enterprises tend to amplify the quantity of green innovations rather than focusing on quality enhancement to project positive signals to markets and government. Such information asymmetries foster a "greenwashing"-analogous behavior, which elevates corporate market value while enabling short-term policy dividend capture[22]. Concurrently, enterprises struggling to anticipate climate policy shifts-and fearing discontinuity in policy incentives-adopt risk-avoidance strategies that generate resource misallocation[23]. This manifests as fragmented investments in short-cycle, low-return green initiatives rather than concentrated commitments to high-quality projects with strategic longevity. Consequently, quantitative proliferation of green innovations outpaces qualitative assurance, catalyzing corporate green innovation bubbles.

Nevertheless, as open systems, enterprises continuously recalibrate their behaviors and strategies in response to environmental dynamics to ensure survival and growth. This inherent adaptiveness serves as a catalyst for organizational innovation[24]. The risks stemming from policy volatility compel enterprises to adopt substantive green innovation as an adaptive strategy. This strategic shift prioritizes long-term value creation while reinforcing corporate social responsibility commitments[25]. Enterprises with heightened social responsibility demonstrate stronger emphasis on environmental and societal impacts during green innovation processes. This focus drives quality enhancement of green innovations while concurrently preparing them for potential regulatory stringency escalation. Concurrently, when confronting policy uncertainties, enterprises exhibit stronger propensity to collaborate with other firms or institutions such as research institutes and universities[26]. This facilitates synergistic innovation-characterized by knowledge sharing, technological complementarity, and resource consolidation-which mitigates resource misallocation and waste while enhancing project sustainability[27]. Consequently, it elevates the quality of corporate green innovations and alleviates green innovation bubbles.

Therefore, this paper proposes the following two research hypotheses:

H1: Increased climate policy uncertainty will exacerbate corporate green innovation bubbles.

H2: Increased in climate policy uncertainty will mitigate corporate green innovation bubbles.

4. Data, Variables and Summary Statistic

4.1. Sample Selection

Focusing on China's A-share listed companies, this investigation encompasses corporate data spanning 2012-2023. The following data preprocessing procedures were implemented on the raw data: (1) Exclusion of financial sector firms; (2) Removal of ST, *ST, and PT-labeled companies; (3) Elimination of observations with substantial missing core variables; (4) Winsorization of continuous variables at the 1st percentile. The final dataset comprises 34,575 valid observations. Primary data sources include the CSMAR database and annual reports disclosed by listed companies.

4.2. Variable Definition

4.2.1. Dependent Variable

Corporate Green Innovation Bubbles (BUB). According to prior research (Geng et al., 2024)[18], we use the number of green patent applications to quantify green innovation quantity. The number of green patents granted is selected as the metric for green innovation quality. Subsequently, the disparity between green innovation quantity and quality is calculated. This disparity is then standardized to gauge corporate green innovation bubbles. A higher standardized value indicates more severe corporate green innovation bubbles.

4.2.2. Independent Variable

Climate Policy Uncertainty (CPU). Following extant scholarly methodologies[28], this study utilizes articles from six authoritative Chinese newspapers-People's Daily, Guangming Daily, Economic Daily, Global Times, Science and Technology Daily, and China News Service-as primary data sources. The Mac BERT deep learning algorithm is employed to automatically identify textual content and extract climate policy uncertainty-related terminologies. Subsequently, we calculate the ratio of climate policy uncertainty-related news articles to total articles within specific time intervals, followed by standardization procedures. This process constructs a city-level Climate Policy Uncertainty (CPU) index in China, which determines firm-specific exposure to climate policy uncertainty. A higher index value indicates greater shocks from climate policy fluctuations a firm's host city.

4.2.3. Control Variables

Table 1. Variable Definition List

Variable Categories	Variable Name	Symbol	Variable Definition
Dependent Variable	Corporate Green Innovation Bubbles	BUB	The difference between the quantity and quality of green patents of enterprises that have been standardized
Independent Variable	Climate Policy Uncertainty	CPU	China Climate Policy Uncertainty Index
Control Variable	Age of Listing	age	$\ln(\text{Current year} - \text{Listing year} + 1)$
	Cashflow Ratio	cashflow	Ratio of net cashflow from operating activities to total assets
	Proportion of Fixed Assets	fixed	Ratio of net fixed assets to total assets
	Proportion of Intangible Assets	intangible	Ratio of net intangible assets to total assets
	Proportion of Independent Directors	indirect	Ratio of the number of independent directors to the size of directors
	Equity Balance	balance	Proportional representation of stock holders (ranked 2-5) versus dominant equity holder
	Industry Competition	hhi	Herfindahl Index calculated by main operation revenue

Control variables are as follows: listing age (age), cash flow ratio (cashflow), fixed assets ratio (fixed), intangible assets ratio (intangible), proportion of independent directors (indirect), equity balance (balance), and industry competition level (hhi). The details of the individual variables are presented in Table 1.

4.3. Summary Statistic

Table 2 presents the descriptive statistics of the dataset. The maximum value of BUB reaches 1.9558, demonstrating the tangible presence of corporate green innovation bubbles among Chinese listed firms. Descriptive statistics of other variables fall within normal ranges and align with prior research findings. Additionally, no multicollinearity issues are detected among the explanatory variables.

Table 2. Descriptive Statistic Results

VarName	Obs	Mean	SD	Min	Median	Max
BUB	34575	-0.0312	0.2796	-0.5029	-0.0955	1.9558
CPU	34575	1.7421	0.7332	0.1998	1.7542	3.8285
age	34575	2.0262	0.9640	0.0000	2.1972	3.4012
cashflow	34575	0.0483	0.0670	-0.1498	0.0474	0.2387
fixed	34575	0.1996	0.1543	0.0019	0.1665	0.6787
intangible	34575	0.0450	0.0506	0.0000	0.0319	0.3281
indirect	34575	37.7421	5.3302	33.3300	36.3600	57.1400
balance	34575	0.7734	0.6200	0.0324	0.6118	2.8315
hhi	34575	0.1195	0.1297	0.0225	0.0760	0.7766

5. Regression Analysis

5.1. Baseline Regression

This paper establishes Model (1) to investigate the relationship between CPU and BUB.

$$BUB_{i,t} = \alpha_0 + \alpha_1 CPU_{i,t} + \alpha_2 Controls_{i,t} + \sum INDUSTRY + \sum YEAR + \varepsilon_{i,t} \quad (1)$$

In Model (1), $BUB_{i,t}$ denotes the level of corporate green innovation bubbles for firm i in year t . Meanwhile, $CPU_{i,t}$ denotes the degree of CPU faced by firm i in year t . $Controls_{i,t}$ are a set of control variables. $\sum INDUSTRY$ and $\sum YEAR$ indicate industry and year fixed effects, respectively. $\varepsilon_{i,t}$ is the error term. If $\alpha_1 > 0$, it suggests that heightened CPU exacerbates corporate BUB; conversely, $\alpha_1 < 0$ would imply that increased CPU mitigates BUB. Notably, all regressions employ firm-clustered standard errors to address within-group heteroskedasticity and serial correlation.

Table 3 presents the baseline regression results. Column (1) reports estimators without control variables, while Column (2) displays results from Model (1). The Column (2) shows that $\alpha_1 = 0.0103$, which passes the 1% significance test, indicating that increased CPU amplifies BUB. This supports H1. Specifically, heightened CPU impedes firms' ability to anticipate policy shifts, negatively impacts decision-making and resource allocation, and ultimately creates a misalignment between the quality and quantity of green innovations-manifesting as corporate green innovation bubbles.

Table 3. Baseline Regression Results

Y=BUB	(1)	(2)
CPU	0.0105***	0.0103***
	(0.0037)	(0.0038)
age		0.0115***
		(0.0035)
cashflow		0.1444***
		(0.0356)
fixed		-0.0460*
		(0.0264)
intangible		-0.0835*
		(0.0449)
indirect		0.0001
		(0.0005)
balance		-0.0020
		(0.0052)
hhi		0.0657***
		(0.0238)
Constant	-0.0495***	-0.0771***
	(0.0066)	(0.0244)
Ind/Year FE	Yes	Yes
N	34575	34575
R ²	0.0414	0.0443
Adj.R ²	0.0390	0.0417

Note: Standard errors in parentheses. ***, **, * indicates significance at the 1%, 5%, 10% level, same as below.

5.2. Robust Tests

5.2.1. The Instrumental Variable Method

Firms exhibiting green innovation bubbles may inherently suffer from governance issues such as managerial myopia and possess weaker risk-bearing capacity, which amplifies bubbles formation under rising CPU. To mitigate reverse causality and omitted variable biases, this paper employs the median CPU of peer firms within the same industry and year but located in different cities as an instrumental variable (IV) to address endogeneity. This median value—calculated from non-local peers in the same industry—serves as an aggregate measure of industry-wide CPU, which is strongly correlated with firm-specific climate policy exposure. Furthermore, the exogeneity condition is satisfied as the median CPU of non-local peers is unlikely to directly influence a firm's green innovation bubbles.

As shown in Table 4, Column (1) confirms a statistically significant correlation between the IV and CPU. The Kleibergen-Paap rk Wald F statistic exceeds the Stock-Yogo 10% critical threshold, rejecting hypothesis about weak instrument. Column (2) reports the second-stage results of the 2SLS regression. The positive coefficient of CPU on BUB, significant with a p-value less than 0.05, corroborates the robustness of baseline regression findings.

5.2.2. Propensity Score Match Approach

To address potential selection bias, this paper implements a propensity score matching (PSM) methodology. Specifically, we dichotomize the CPU at its median value and conducts 1:1 and 1:3 nearest neighbor matching. Post-matching samples are then re-estimated. As reported in Columns (3) and (4) of Table 4, the coefficients of CPU on BUB are 0.0124 (significant at 1%)

and 0.0090 (significant at 5%), respectively. These results further demonstrate robust estimator of baseline regression.

5.2.3. Double/Debiased Machine Learning Regression

To obtain unbiased estimates of CPU’s effect on BUB, following prior research[29], we incorporate quadratic terms of control variables to explain nonlinear relationships and employ a Lasso-based double/debiased machine learning model. The formal models are specified in Models (2) and (3). $X_{i,t}$ denotes control variables. $U_{i,t}$ is the error term with conditional mean zero. θ_0 represents the target unbiased estimator.

$$BUB_{i,t} = \theta_0 CPU_{i,t} + g(X_{i,t}) + U_{i,t} \tag{2}$$

$$E(U_{i,t} | CPU_{i,t}, X_{i,t}) = 0 \tag{3}$$

As shown in column (5) of Table 4, the double/debiased machine learning regression yields a CPU coefficient on BUB of 0.0097, which is virtually identical to the baseline result and also statistically significant, demonstrating the robustness of our finding.

Table 4. Robust Test Results I

	2SLS		PSM		DDML
	Step1	Step2	1:1	1:3	Lasso
	(1)	(2)	(3)	(4)	(5)
	CPU	BUB	BUB	BUB	BUB
CPU		0.0438**	0.0124***	0.0090**	0.0097**
		(0.0190)	(0.0043)	(0.0039)	(0.0038)
IV	0.5332***				-
	(0.0320)				-
age	-0.0068	0.0117***	0.0121***	0.0121***	-
	(0.0066)	(0.0035)	(0.0037)	(0.0035)	-
cashflow	-0.1276*	0.1481***	0.1823***	0.1436***	-
	(0.0725)	(0.0358)	(0.0440)	(0.0362)	-
fixed	-0.3941***	-0.0326	-0.0426	-0.0447	-
	(0.0513)	(0.0273)	(0.0277)	(0.0273)	-
intangible	-0.0536	-0.0805*	-0.1197**	-0.0842*	-
	(0.1392)	(0.0445)	(0.0489)	(0.0462)	-
indirect	0.0015	0.0001	-0.0001	0.0003	-
	(0.0011)	(0.0005)	(0.0005)	(0.0005)	-
balance	-0.0144	-0.0012	-0.0061	-0.0006	-
	(0.0101)	(0.0052)	(0.0052)	(0.0053)	-
hhi	0.0591	0.0682***	0.0745***	0.0628***	-
	(0.0653)	(0.0239)	(0.0271)	(0.0241)	-
Constant	-	-	-0.0722***	-0.0845***	0.0001
	-	-	(0.0243)	(0.0248)	(0.0031)
Ind/Year FE	Yes	Yes	Yes	Yes	Yes
N	34356	34356	18879	31050	34575
R ²	-	-0.0026	0.0524	0.0432	-
Adj.R ²	-	-	0.0476	0.0402	-
Kleibergen-Paap rk Wald F statistic	2277.202	-	-	-	-
	(16.38)				

5.2.4. Other Robust Tests

In addition, this study employs a series of robustness checks through the following approaches. First, following prior research[18], we substitute the dependent variable with two alternative measures: the disparity between the quantity and quality of green invention patents (BUB1) and the disparity between the quantity and quality of green utility patents (BUB2). Regression results based on Model (1) (columns (1) and (2) of Table 5) show that the estimators of CPU on BUB1 and BUB2 are 0.0088 and 0.0061, respectively.

Second, given the potential lagged effects of policy-where CPU may influence subsequent corporate green innovation behaviors-we introduce one-period and two-period lags for CPU to extend the observation window and mitigate endogeneity concerns. Results (columns (3) and (4) of Table 5) indicate that the coefficients of CPU on BUB are 0.0179 (one-period lag) and 0.0156 (two-period lag).

Third, to enhance model precision, we incorporate industry-year interaction fixed effects into the baseline regression framework. Results (column (5) of Table 5) show a CPU coefficient on BUB of 0.0094.

Finally, to isolate the impact of the COVID-19 pandemic, we exclude firm-year observations from 2020 and 2021. Results (column (6) of Table 5) reveal a CPU coefficient on BUB of 0.0112. The robustness test results above are statistically significant, which indicates that H1 is very robust.

Table 5. Robust Test Results II

	(1)	(2)	(3)	(4)	(5)	(6)
	BUB1	BUB2	BUB	BUB	BUB	BUB
CPU	0.0088**	0.0061**			0.0094**	0.0112***
	(0.0036)	(0.0026)			(0.0040)	(0.0039)
L.CPU			0.0179***			
			(0.0058)			
L2.CPU				0.0156***		
				(0.0057)		
age	0.0123***	-0.0049***	0.0126***	0.0159***	0.0113***	0.0128***
	(0.0034)	(0.0018)	(0.0046)	(0.0056)	(0.0035)	(0.0037)
cashflow	0.1464***	0.0138	0.1675***	0.1659***	0.1496***	0.1356***
	(0.0344)	(0.0298)	(0.0388)	(0.0403)	(0.0376)	(0.0387)
fixed	-0.0523**	-0.0019	-0.0482*	-0.0409	-0.0403	-0.0491*
	(0.0254)	(0.0115)	(0.0279)	(0.0295)	(0.0270)	(0.0267)
intangible	-0.0657	-0.0495	-0.0785	-0.0532	-0.0837*	-0.0710
	(0.0444)	(0.0315)	(0.0482)	(0.0503)	(0.0459)	(0.0493)
indirect	0.0002	-0.0005	0.0002	0.0003	0.0001	0.0004
	(0.0005)	(0.0003)	(0.0005)	(0.0006)	(0.0005)	(0.0005)
balance	-0.0013	0.0007	-0.0014	-0.0020	-0.0012	-0.0021
	(0.0050)	(0.0021)	(0.0055)	(0.0059)	(0.0052)	(0.0054)
hhi	0.0516**	0.0978***	0.0737***	0.0826***	0.0455	0.0800***
	(0.0210)	(0.0250)	(0.0266)	(0.0300)	(0.0432)	(0.0274)
Constant	-0.0814***	0.0081	-0.1014***	-0.1143***	-0.0740***	-0.0890***
	(0.0232)	(0.0145)	(0.0278)	(0.0299)	(0.0257)	(0.0253)
Ind/Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Ind×Year FE	No	No	No	No	Yes	No
N	34575	34575	29839	25635	34575	27405
R ²	0.0567	0.0048	0.0462	0.0467	0.0649	0.0430
Adj.R ²	0.0541	0.0021	0.0432	0.0433	0.0395	0.0397

5.3. Mechanism Analysis

Financial slack, defined as the strategic innovation resources available to firms after meeting essential financial obligations[30], serves as a buffer[31], helping firms adapt to new environments when confronting climate policy fluctuations. This effectively mitigates resource misallocation under climate policy uncertainty, strengthens firms' resilience to climate policy risks, and redirects capital toward high-potential and valuable green innovation projects rather than prioritizing mere quantity. Furthermore, based on the resource-based theory, higher financial slack in uncertain environments enhances firms' competitiveness, attracts external partners in green innovation, improves innovation quality, and ultimately alleviates green innovation bubbles.

Following prior studies[32],[33], this study employs the quick ratio (Quick) and Z-Score (ZScore) to measure financial slack (FS). A higher quick ratio indicates greater liquidity of assets and more deployable financial resources. Similarly, a higher Z-Score reflects stronger financial health and risk resilience. Both metrics serve as robust proxies for financial slack. Model (4) specifies the Z-Score calculation, where X_1 = Operating Capital/Total Assets, X_2 = Retained Earnings/Total Assets, X_3 = EBIT/Total Assets, X_4 = Market Value of Equity/Carrying Value of Total Liabilities, X_5 = Operating Income/Total Assets.

$$Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 0.999X_5 \quad (4)$$

We use Model (5) to test the moderating effect of financial slack. If β_1 is positive and the interaction term between CPU and FS β_4 is negative, financial slack mitigates climate policy uncertainty's exacerbation of green innovation bubbles.

$$BUB_{i,t} = \beta_0 + \beta_1 CPU_{i,t} + \beta_3 FS_{i,t} + \beta_4 CPU_{i,t} \times FS_{i,t} + \beta_5 Controls_{i,t} + \sum INDUSTRY + \sum YEAR + \varepsilon_{i,t} \quad (5)$$

As shown in Table 6, the coefficients of CPU on BUB are both significantly positive, while the interaction terms between CPU and both FS proxies (Quick and Z-Score) are significantly negative. All the above results are statistically significant, which indicates that financial slack is one of the ways to deflate the corporate green innovation bubbles caused by increased climate policy uncertainty.

Table 6. Moderating Analysis Results

Y=BUB	(1)	(2)
CPU	0.0111***	0.0107***
	(0.0039)	(0.0039)
Quick	-0.0059***	
	(0.0009)	
CPU×Quick	-0.0018**	
	(0.0008)	
ZScore		-0.0027***
		(0.0004)
CPU×ZScore		-0.0007**
		(0.0003)
age	0.0074**	0.0106***
	(0.0036)	(0.0034)
cashflow	0.1601***	0.1809***
	(0.0360)	(0.0372)
fixed	-0.0669**	-0.0638**
	(0.0271)	(0.0265)
intangible	-0.1087**	-0.1036**
	(0.0448)	(0.0449)
indirect	0.0001	0.0002
	(0.0005)	(0.0005)
balance	-0.0014	-0.0014
	(0.0051)	(0.0051)
hhi	0.0666***	0.0650***
	(0.0238)	(0.0237)
Constant	-0.0467**	-0.0564**
	(0.0224)	(0.0222)
Ind/Year FE	Yes	Yes
N	34575	34575
R ²	0.0461	0.0469
Adj.R ²	0.0434	0.0442

6. Conclusion and Implication

6.1. Conclusion

The findings of this study are as follows: Increased climate policy uncertainty significantly exacerbates corporate green innovation bubbles, manifesting as a misalignment between the quantity and quality of green innovations. This conclusion remains robust after a series of robust checks. Furthermore, financial slack effectively mitigates the amplification of corporation green innovation bubbles caused by rising climate policy uncertainty.

6.2. Political Implication

First of all, for government departments, frequent changes and uncertainties in climate policies should be minimized when making policies, and clear and long-term policy guidance should be provided to help enterprises carry out long-term green innovation strategic planning. When formulating green innovation subsidy policies, it is necessary to use a variety of subsidy methods to encourage enterprises to increase investment in green innovation projects, so as to guide enterprises to pursue green innovation quality. Meanwhile, it is essential to shift from the

pure project quantity subsidy to the subsidy based on the quality of innovation results and the actual environmental benefits. This requires the regulatory authorities to strengthen the supervision and management of enterprises' green innovation behaviors, establish a scientific green innovation evaluation index system, and strictly evaluate and review enterprises' innovation achievements, so as to curb the breeding of green innovation bubbles of corporates. For enterprises themselves, first of all, they should be aware of the important role of financial slack in the consequence of shocks from climate policy fluctuations on corporate green innovation bubbles, and rationally plan and manage financial slack resources. Secondly, in the current climate policy uncertainty environment, enterprises should pay attention to corporate strategic planning and risk management, and establish a sound risk early warning mechanism and crisis response strategy to cope with the unpredictability of policy fluctuations. In addition, enterprises should actively carry out in-depth cooperation and exchanges with other enterprises and scientific research institutions in the same industry to achieve collaborative innovation. It is worth mentioning that enterprises can take the initiative to maintain close communication with government departments to keep abreof policy trends and development directions. At the same time, enterprises can also feedback the problems and difficulties encountered in the process of green innovation projects to the government departments, so as to provide reference for the government to formulate more reasonable policies. Finally, enterprises should actively fulfill their social responsibilities, recognize the vital role of green innovation in the sustainable development of the environment and society, pay attention to the quality and actual effects of innovation projects, and avoid the emergence of corporate green innovation bubbles.

Acknowledgments

This research was funded by the Shandong Provincial Natural Science Foundation (Grant no. ZR2021QG020).

References

- [1] Mehta L, Adam H N, Srivastava S. Unpacking uncertainty and climate change from 'above' and 'below' [J]. *Regional Environmental Change*, 2019, 19: 1529-1532. DOI: 10.1007/s10113-019-01539-y
- [2] Dongbei Bai, Lizhao Du, Yang Xu, Shujaat Abbas, Climate policy uncertainty and corporate green innovation: Evidence from Chinese A-share listed industrial corporations, *Energy Economics*, Volume 127, Part B, 2023, 107020, <https://doi.org/10.1016/j.eneco.2023.107020>.
- [3] Peng Zhou, Frank M. Song, Xiaoqi Huang, Environmental regulations and firms' green innovations: Transforming pressure into incentives, *International Review of Financial Analysis*, Volume 86, 2023, 102504, ISSN 1057-5219, <https://doi.org/10.1016/j.irfa.2023.102504>.
- [4] Delmas, M. A., Montes, M. j., & Montes-Sancho, M. J. (2010). Voluntary agreements to improve environmental quality: Symbolic and substantive cooperation. *Strategic Management Journal*, 31(6), 575-601. <https://doi.org/10.1002/smj.826>
- [5] Borozan, D., & Pirgaip, B. (2024). Climate policy uncertainty and firm-level carbon dioxide emissions: Assessing the impact in the U.S. market. *Business Strategy and the Environment*, 33(6), 5920-5938. <https://doi.org/10.1002/bse.3784>
- [6] Asil Azimli, The impact of climate policy uncertainty on firm value: Does corporate social responsibility engagement matter? *Finance Research Letters*, Volume 51, 2023, 103456, ISSN 1544-6123, <https://doi.org/10.1016/j.frl.2022.103456>.
- [7] Persakis, A. The impact of climate policy uncertainty on ESG performance, carbon emission intensity and firm performance: evidence from Fortune 1000 firms. *Environ Dev Sustain* 26, 24031-24081 (2024). <https://doi.org/10.1007/s10668-023-03634-x>

- [8] Shuhai Niu, Juan Zhang, Renfu Luo, Yanchao Feng, How does climate policy uncertainty affect green technology innovation at the corporate level? *New evidence from China*, *Environmental Research*, Volume 237, Part 2, 2023, 117003, <https://doi.org/10.1016/j.envres.2023.117003>.
- [9] Lili Zhao, Yibing Ma, Na Chen, Fenghua Wen, How does climate policy uncertainty shape corporate investment behavior? *Research in International Business and Finance*, Volume 74, 2025, 102696, <https://doi.org/10.1016/j.ribaf.2024.102696>.
- [10] Huang, W., Chau, K.Y., Kit, I.Y., Nureen, N., Irfan, M., Dilanchiev, A., 2022. Relating sustainable business development practices and information management in promoting digital green innovation: evidence from China. *Front. Psychol.* 13, 930138. DOI: 10.3389/fpsyg.2022.930138
- [11] Yulin Liu, Lin Chen, Zhiling Cao, Fenghua Wen, Uncertainty breeds opportunities: Assessing climate policy uncertainty and its impact on corporate innovation, *International Review of Financial Analysis*, Volume 96, Part A, 2024, 103560, <https://doi.org/10.1016/j.irfa.2024.103560>.
- [12] Zheng, M., Feng, G.-F., Jiang, R.-A., & Chang, C.-P. (2023). Does environmental, social, and governance performance move together with corporate green innovation in China? *Business Strategy and the Environment*, 32(4), 1670–1679. <https://doi.org/10.1002/bse.3211>
- [13] Javeed, S. A., Teh, B. H., Ong, T. S., Chong, L. L., Abd Rahim, M. F. B., & Latief, R. (2022). How Does Green Innovation Strategy Influence Corporate Financing? Corporate Social Responsibility and Gender Diversity Play a Moderating Role. *International Journal of Environmental Research and Public Health*, 19(14), 8724. <https://doi.org/10.3390/ijerph19148724>
- [14] Lizhao Du, Mianjin Wei, Shaoxin Zhang, Junyu Pan, Unveiling the policy intervention effects of natural resource regulation on firm-level pollution emissions: Evidence from China's restrained land supply, *Resources Policy*, Volume 86, Part A, 2023, 104081, <https://doi.org/10.1016/j.resourpol.2023.104081>.
- [15] Liqian Liu, Amei Feng, Mingxia Liu, The effect of green innovation on corporate financial performance: Does quality matter? *Finance Research Letters*, Volume 62, Part B, 2024, 105255, <https://doi.org/10.1016/j.frl.2024.105255>.
- [16] Wei Kong, Does financial risk exacerbate the risk of low-quality green innovation? *Pacific-Basin Finance Journal*, Volume 90, 2025, 102673, <https://doi.org/10.1016/j.pacfin.2025.102673>.
- [17] Arthur G. Kraft, Rahul Vashishtha, Mohan Venkatachalam; Frequent Financial Reporting and Managerial Myopia. *The Accounting Review* 1 March 2018; 93 (2): 249–275. <https://doi.org/10.2308/accr-51838>
- [18] Yuan Geng, Jinyu Chen, Ran Liu, ESG rating disagreement and corporate green innovation bubbles: Evidence from Chinese A-share listed firms, *International Review of Financial Analysis*, Volume 95, Part B, 2024, 103495, ISSN 1057-5219, <https://doi.org/10.1016/j.irfa.2024.103495>.
- [19] Hongyun Huang, William Mbanye, Fengrong Wang, Malin Song, Yuzhang Wang, Climbing the quality ladder of green innovation: Does green finance matter? *Technological Forecasting and Social Change*, Volume 184, 2022, 122007, <https://doi.org/10.1016/j.techfore.2022.122007>.
- [20] Khaled Mokni, Leila Hedhili Zaier, Manel Youssef, Sami Ben Jabeur, Quantile connectedness between the climate policy and economic uncertainty: Evidence from the G7 countries, *Journal of Environmental Management*, Volume 351, 2024, 119826, <https://doi.org/10.1016/j.jenvman.2023.119826>.
- [21] Connelly, B. L., Certo, S. T., Ireland, R. D., & Reutzel, C. R. (2011). Signaling theory: A review and assessment. *Journal of Management*, 37(1), 39-67. <https://doi.org/10.1177/0149206310388419>
- [22] Mao Xu, Ying Kei Tse, Ruoqi Geng, Zhenyuan Liu, Andrew Potter, Greenwashing and market value of firms: An empirical study, *International Journal of Production Economics*, Volume 284, 2025, 109606, <https://doi.org/10.1016/j.ijpe.2025.109606>.
- [23] Chengming Li, Wei Tang, Feiyan Liang, Zeyu Wang, The impact of climate change on corporate ESG performance: The role of resource misallocation in enterprises, *Journal of Cleaner Production*, Volume 445, 2024, 141263, <https://doi.org/10.1016/j.jclepro.2024.141263>.

- [24] Matti Tuominen, Arto Rajala, Kristian Möller, How does adaptability drive firm innovativeness? *Journal of Business Research*, Volume 57, Issue 5, 2004, Pages 495-506, [https://doi.org/10.1016/S0148-2963\(02\)00316-8](https://doi.org/10.1016/S0148-2963(02)00316-8).
- [25] Hong Vo, Tien Nguyen, Hieu V. Phan, Building a sustainable future: The role of corporate social responsibility in climate policy uncertainty management, *Finance Research Letters*, Volume 60, 2024, 104831, <https://doi.org/10.1016/j.frl.2023.104831>.
- [26] David B. Audretsch, Maksim Belitski, Knowledge collaboration, firm productivity and innovation: A critical assessment, *Journal of Business Research*, Volume 172, 2024, 114412, <https://doi.org/10.1016/j.jbusres.2023.114412>.
- [27] Tencati, A., Zsolnai, L. The Collaborative Enterprise. *J Bus Ethics* 85, 367–376 (2009). <https://doi.org/10.1007/s10551-008-9775-3>
- [28] Ma, YR., Liu, Z., Ma, D. et al. A news-based climate policy uncertainty index for China. *Sci Data* 10, 881 (2023). <https://doi.org/10.1038/s41597-023-02817-5>
- [29] Chernozhukov, V., Chetverikov, D., Demirer, M., Duflo, E., Hansen, C., Newey, W., & Robins, J. (2018). Double/debiased machine learning for treatment and structural parameters. *The Econometrics Journal*, 21(1), C1-C68. <https://doi.org/10.1111/ectj.12097>
- [30] JingJing Zhang, Jiancheng Guan, The time-varying impacts of government incentives on innovation, *Technological Forecasting and Social Change*, Volume 135, 2018, Pages 132-144, ISSN 0040-1625, <https://doi.org/10.1016/j.techfore.2018.04.012>.
- [31] Feng Guo, Bo Zou, Xiaofei Zhang, Qingwen Bo, Kai Li, Financial slack and firm performance of SMMEs in China: Moderating effects of government subsidies and market-supporting institutions, *International Journal of Production Economics*, Volume 223, 2020, 107530, ISSN 0925-5273, <https://doi.org/10.1016/j.ijpe.2019.107530>.
- [32] Lins, K. V., Servaes, H., & Tamayo, A. (2017). Social capital, trust, and firm performance: The value of corporate social responsibility during the financial crisis. *The Journal of Finance*, 72(4), 1785-1824. <https://doi.org/10.1111/jofi.12505>
- [33] Altman, E. I. (1968). Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. *The Journal of Finance*, 23(4), 589-609. <https://doi.org/10.1111/j.1540-6261.1968.tb00843.x>