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The Impact of Climate Policy Uncertainty on the ESG Performance of Enterprises

Zhi Zhang [1,†], Yanhong Feng [2,†], Hongwei Zhou [3,*], Liming Chen [3] and Yi Liu [3]

[1] School of Economics and Trade, Hunan University, Changsha 410006, China; zhangzhi1996@hnu.edu.cn
[2] School of Economics Management and Law, University of South, Hengyang 421200, China; 2021000152@usc.edu.cn
[3] School of Finance and Statistics, Hunan University, Changsha 410006, China; chenliming@hnu.edu.cn (L.C.); liuyi0327@163.com (Y.L.)
* Correspondence: zhouhongwei@hnu.edu.cn; Tel.: +86-17611316882
† These authors contributed equally to this work.

Abstract: In the context of addressing climate change, the uncertainty of climate policies has intensified the environmental and regulatory risks faced by enterprises, forcing them to adjust their strategies for fulfilling ESG responsibilities in pursuit of sustainable development. This paper uses panel data from listed non-financial enterprises on China's Shanghai and Shenzhen A-share markets from 2011 to 2022, employing a fixed-effects panel model to examine the impact of climate policy uncertainty on corporate ESG performance. The findings indicate that climate policy uncertainty significantly hampers the ESG performance of enterprises. The mechanism analysis reveals that climate policy uncertainty negatively affects ESG performance by deepening corporate financing constraints and increasing short-term financial performance. The heterogeneity analysis shows that in terms of ownership structure, the negative impact of climate policy uncertainty on the ESG performance of state-owned enterprises is relatively weaker. In terms of industry heterogeneity, climate policy uncertainty suppresses the ESG performance of enterprises in technology-intensive industries. From a regional perspective, climate policy uncertainty has a stronger inhibitory effect on the ESG performance of enterprises in eastern China. This study provides valuable insights for both national climate policy formulation and corporate efforts to enhance ESG performance.

Keywords: climate policy uncertainty; corporate ESG performance; financing constraints; financial performance

Citation: Zhang, Z.; Feng, Y.; Zhou, H.; Chen, L.; Liu, Y. The Impact of Climate Policy Uncertainty on the ESG Performance of Enterprises. *Systems* **2024**, *12*, 495. https://doi.org/10.3390/systems12110495

Academic Editor: Shanyue Jin

Received: 25 September 2024
Revised: 11 November 2024
Accepted: 14 November 2024
Published: 16 November 2024

1. Introduction

Global climate change has become one of the most pressing challenges facing the world today. In response, many countries have formulated climate policies. Although the global trend of climate change may remain stable in the short term, the uncertainty surrounding extreme weather events and natural climate fluctuations contributes to climate policy uncertainty. Furthermore, frequent adjustments and updates to government policies make it difficult for individuals and businesses to anticipate future policy environments [1]. For instance, the carbon reduction targets and measures established under the Paris Agreement, as well as those developed by individual countries, are often adjusted in response to changes in political and economic conditions. Additionally, discrepancies in the intensity of policy implementation further contribute to uncertainty. While central governments may set clear policy objectives, local governments can vary in their strength and effectiveness of enforcement, which further exacerbates climate policy uncertainty. Therefore, the Climate Policy Uncertainty (CPU) Index serves as a comprehensive proxy indicator that not only fully captures the risks associated with climate change but also reflects the uncertainty related to climate policies.

Frequent changes in climate policies pose significant challenges to firms, as constantly shifting compliance requirements necessitate constant adjustments to their business strategies. Such adjustments lead to a notable increase in corporate compliance costs (Ren et al., 2022) [2]. Moreover, the unpredictable nature of climate policies amplifies firms' risk-averse behaviors, making them more cautious in financial management. As a result, firms are more inclined to allocate funds to short-term projects with certain returns rather than investing in long-term projects with uncertain returns, such as green technologies and infrastructure. This trend ultimately suppresses corporate investment efforts in environmental technology and green transformation (Dai & Zhu, 2024) [3]. Given these impacts, quantifying the uncertainty and dynamic nature of climate policies is crucial for aiding corporate decision making. The current primary measurement approach leverages text mining techniques, utilizing news articles from major newspapers as data sources, which are processed through the MacBERT deep learning model and standardized following the method of Baker et al. (2016) [4]. The uncertainty index constructed through this method exhibits excellent traceability, temporal dynamism, and sustainability.

Climate policy uncertainty has exerted a profound influence on corporate decision making and sustainable development. Among the key factors shaping corporate growth are environmental, social, and governance (ESG) performance, which largely reflects a company's efforts to address climate change, support national green development initiatives, and manage the risks associated with ecological and climate changes. Consumers, stakeholders, and investors expect enterprises to demonstrate their performance in environmental and social responsibilities during periods of uncertainty. First, in terms of environmental responsibility, climate policy uncertainty heightens the risks associated with corporate investments in green technologies and environmental protection measures, prompting firms to adopt a more cautious approach in fulfilling their environmental obligations. Second, the fulfillment of social responsibility is also shaped by the policy environment. Public and stakeholder expectations regarding corporate social responsibility (CSR) are closely aligned with policy directions, and when climate policy uncertainty increases, corporate investments in CSR initiatives may be adversely affected. Moreover, corporate governance plays a critical role in addressing climate policy uncertainty. Enterprises need to adjust their internal management and decision-making processes to enhance flexibility and adaptability in response to policy changes, thereby improving governance standards. However, corporate managers must balance the costs of implementing green technologies, carbon taxes, and carbon trading against the potential returns from green investments when making decisions about corporate sustainability actions. Faced with uncertain climate policy shifts, will enterprises adopt proactive strategies to fulfill social responsibilities and mitigate climate risks, or will they take a cautious, wait-and-see approach, maintaining their current development trajectory? This question remains largely unexplored due to a lack of available data.

As the risks associated with climate change garner increasing attention, research on climate policy uncertainty has gradually become the central focus of scholars. From a microeconomic perspective, existing studies have primarily concentrated on the impact of climate policy uncertainty on corporate financial performance indicators and investment decisions [5–7]. Meanwhile, in current research, the economic benefits of ESG performance are often illustrated through its positive effects on financial performance [8–11]. Overall, there are only a limited number of studies examining the effects of climate change on corporate ESG performance [12], as well as the impact of climate policy uncertainty on corporate ESG disclosures [13,14]. However, there is limited discussion regarding the relationship between climate policy uncertainty and corporate ESG performance, and no consensus has been reached. Additionally, the mechanisms through which climate policy uncertainty influences corporate ESG performance remain largely unexplored. Investigating how increased climate policy uncertainty affects corporate ESG performance can provide valuable data to support national climate policy formulation, enabling governments to design policies that incentivize or facilitate improvements in corporate ESG performance. Furthermore, such

research offers critical guidance to enterprises seeking to enhance their ESG performance and achieve sustainable development, contributing to green, healthy, and high-quality economic growth through improving environmental, social responsibility, and governance outcomes. Therefore, this paper investigates the impact of climate policy uncertainty on corporate ESG performance, utilizing panel data from non-financial enterprises listed on China's Shanghai and Shenzhen A-share markets between 2011 and 2022, and employs econometric models to examine the effects of climate policy uncertainty on corporate ESG performance and its underlying mechanisms.

Compared to existing studies, the contributions of this paper are primarily reflected in the following aspects: First, this paper introduces a new research perspective by focusing on corporate ESG performance under climate policy uncertainty. While numerous studies have analyzed the effects of policy uncertainty on corporate green development or financial performance, the growing attention from investors, the public, and other stakeholders to environmental protection, resource conservation, and climate governance has led to widespread recognition of corporate ESG disclosures. However, few existing studies have employed econometric models to empirically test the impact of climate policy uncertainty on corporate ESG performance [11]. Building on this, the paper selects ESG performance—an increasingly prominent metric in academia—as a quantitative indicator of corporate green development performance, focusing on the impact of climate policy uncertainty on overall corporate ESG performance and its subcategories, including environmental performance, social responsibility performance, and governance performance. This offers a meaningful addition to existing research perspectives and conclusions.

Second, in terms of mechanism testing, this paper adopts a novel approach by examining the effects of climate policy uncertainty on corporate ESG performance from the perspectives of financing constraints and short-term financial performance, based on enterprises' operational conditions and objectives. The empirical results demonstrate that under the influence of climate policy uncertainty, enterprises facing financing constraints and driven by short-term financial goals reduce their investment in ESG projects, resulting in a decline in ESG performance. This offers a new perspective for analyzing the internal mechanisms by which climate policy uncertainty affects corporate ESG performance and offers valuable insights for policymakers aiming to improve corporate ESG outcomes [15].

Additionally, this paper further investigates the heterogeneous effects of climate policy uncertainty on corporate ESG performance. First, state-owned and non-state-owned enterprises exhibit different sensitivities to climate policies. Second, differences in the production factors and methods across industries result in varying sensitivities and adaptive capacities to climate policy changes [16]. Moreover, regional differences in policy enforcement, economic structure, and environmental priorities may lead to diverse ESG strategies and outcomes in response to climate policy uncertainty. However, these aspects have not been adequately explored in existing research. Therefore, this paper focuses on analyzing the heterogeneous impacts of climate policy uncertainty on corporate ESG performance across ownership structures, industries, and regions, providing valuable insights for enterprises seeking to implement more targeted climate risk management strategies.

The remainder of this paper is organized as follows: Section 2 provides a literature review and theoretical analysis; Section 3 presents the baseline regression analysis and robustness checks; Section 4 includes further discussion, such as mechanism testing and heterogeneity analysis; and Section 5 concludes the paper.

2. Literature Review and Hypothesis

2.1. Literature Review

Uncertain major political or economic events have a profound impact on both the global and domestic macroeconomic environments, affecting employment and economic stability, thereby making uncertainty a critical concern for policymakers [17]. In particular, the unpredictability of climate change has given rise to uncertainty in climate-related

policies, commonly referred to as climate policy uncertainty. In the context of global climate upheaval, climate policy uncertainty has become a research hotspot.

First and foremost, an effective measurement of climate policy uncertainty forms the basis of empirical research. With the development of big data analytics, text mining and machine learning methods have been increasingly employed to quantify policy uncertainty. Drawing on the methodology used by Baker et al. (2016) [4] to construct the Economic Policy Uncertainty (EPU) Index, Gavriilidis developed a U.S. Climate Policy Uncertainty (CPU) Index by counting the number of articles related to climate, uncertainty, and regulatory legislation published in eight major newspapers [18]. By comparing the frequency of index peaks with actual changes in climate policies, the accuracy and reliability of the index were validated. As the world's largest carbon emitter, China plays a significant role in global greenhouse gas emissions. Lee and Cho hypothesized that substantial climate-related uncertainties may originate from China [1]. They utilized Twitter data from global users to develop China-specific Climate Uncertainty (TC-CU) and Climate Policy Uncertainty (TC-CPU) Indices. Through a correlation analysis between the U.S. and China CPU Indices, they provided further evidence of the indices' validity. Moreover, Ma et al. also used Chinese news articles and, for the first time, applied the MacBERT deep learning algorithm to extract features from mainstream media reports on climate policy uncertainty [19]. This approach enhanced the flexibility and generalizability of the model, reducing the biases associated with text analysis models based on specific rules or dictionaries. Ultimately, they developed a three-tiered China Climate Policy Uncertainty Index at the national, provincial, and municipal levels.

In terms of the economic effects of climate policy uncertainty, existing research has primarily focused on its impact on corporate financial performance indicators, environmental performance, social responsibility performance, and investment decisions. First, climate policies directly affect the business environment, which subsequently affects corporate financial performance. Wang and Li used a Generalized Autoregressive Conditional Heteroskedasticity Mixed-Data Sampling (GARCH-MIDAS) model to confirm the predictive power of climate and climate policy uncertainty on stock market volatility, indicating that climate policy uncertainty can significantly affect stock returns [5]. Azimli explored the negative impact of climate policy uncertainty on corporate valuations and further empirically demonstrated that corporate social responsibility can mitigate this negative effect [6]. Zhang et al. also found that the insurance function of reputational capital plays a crucial role in enterprises with high levels of social responsibility [20]. Second, when climate policy uncertainty increases, enterprises may adopt emission-reducing technologies to lower pollution, thereby improving their environmental performance [14]. However, Persakis argued that climate policy uncertainty negatively affects corporate carbon emissions performance [21]. Third, under conditions of high climate policy uncertainty, enterprises with strong corporate governance and financial flexibility tend to be more proactive in their social responsibility activities [22]. Fourth, climate policy uncertainty reflects climate risk to some extent, directly affecting investment risk and influencing decision making by corporate managers and investors [22]. Research on the impact of climate policy uncertainty on investment can generally be categorized into two aspects: corporate investment and external investment. On the one hand, delayed returns on investments increase the risk of stranded assets due to climate policy changes, affecting managers' investment decisions [23]. For example, Ren et al. used a dynamic threshold model to show that climate policy uncertainty has no significant impact on high-level investments but significantly affects low-level investments [24]. Additionally, the negative impact of climate policy uncertainty is pronounced in the mining industry, while its effect is notably positive in sectors like power, heat, natural gas, and water supply. On the other hand, external investors exhibit greater caution in capital investments in enterprises sensitive to climate risks, expecting these enterprises to take effective measures to mitigate or offset the potential risks caused by climate policy changes [25]. Huynh and Xia, in their study on bond yields and climate change, similarly found that as market sensitivity to climate change risk increases,

investors are more willing to pay higher premiums for bonds issued by environmentally responsible enterprises [26].

As climate change risks and corporate ESG performance garner increasing attention, the relationship between climate risks or climate policy uncertainty and corporate ESG performance has gained prominence in academic research. Relevant studies can be broadly divided into two categories: First, several studies suggest that climate risk not only promotes the growth of ESG disclosures but also imposes higher demands on corporate ESG performance. Pérez et al. noted that the majority of ESG growth stems from the environmental component, being driven by responses to climate change [21]. Addressing climate change issues has become a widely accepted practice in the global private equity industry. In China's private equity sector, fund-limited partners (LPs) are rapidly increasing and refining their ESG evaluation criteria for general partner (GP) teams. Cepni et al. found that during periods of high climate uncertainty, the transmission of shocks between traditional and ESG assets significantly decreases, suggesting that ESG investments can provide diversified returns for traditional investors, helping them withstand climate-driven shocks [12]. Chen et al., in their study of the ESG performance and financial data of 100 global manufacturing enterprises from 2005 to 2020, used a multilevel quadratic growth model to empirically test the relationship between climate risk and opportunity disclosures (CCR) and found no multiplier effect on the financial performance of manufacturing enterprises [16]. Second, some studies have focused on the impact of climate policy uncertainty on corporate ESG disclosures or performance. Hoang conducted an empirical study using data from U.S. enterprises, showing that enterprises increased their ESG disclosures under high climate policy uncertainty [27]. Corporate governance characteristics also played a moderating role: enterprises with more frequent audit committee meetings, tighter financial constraints, more earnings manipulation, higher emissions, and greater awareness of climate change risks were more deeply affected by climate policy uncertainty [28]. Persakis suggested that climate policy uncertainty has a positive impact on ESG performance but a negative impact on corporate performance and carbon emissions performance [29]. Moreover, during periods of high uncertainty, when investor sentiment is pessimistic, enterprises tend to enhance their ESG performance, particularly to address stakeholder concerns.

2.2. Hypothesis

Climate policy uncertainty (CPU) refers to the uncertainty arising from the ambiguity surrounding the enactment, timing, and enforcement strength and methods of government climate policies. In the ESG evaluation framework, environmental performance (E) primarily assesses a company's commitment to environmental protection, while the assessment of social responsibility (S) includes evaluating actions that support social development, such as protecting employee rights, ensuring customer satisfaction, and contributing to the growth of the communities in which the company operates. These behaviors reflect a company's commitment to social responsibility and its positive impact on society. Corporate governance performance (G) mainly evaluates the rationality of a company's internal management structure, the democratic and transparent nature of its decision-making processes, and the protection of stakeholders' interests. Climate policy uncertainty affects environmental performance, social responsibility, and corporate governance performance, ultimately influencing overall ESG performance [30].

First, when climate policy uncertainty is high, enterprises may delay or reduce investments in environmental technologies and sustainable projects due to the increased risk of returns under uncertain future policies [31]. Additionally, concerns over the risk of stranded resources invested in environmental technologies and process innovations further discourage enterprises from pursuing such investments [32]. Furthermore, in response to potential policy changes, enterprises may face difficulties in effectively allocating resources, leading to delays in the implementation of environmental measures and a reduction in efficiency.

Second, in the context of climate policy uncertainty, enterprises may prioritize maintaining current production and development while reducing investments in social responsibility initiatives [5]. When confronted with numerous uncertainties and challenges, enterprises tend to adopt conservative decision-making strategies to reduce operational costs and mitigate the risk of insufficient capital. Consequently, climate policy uncertainty may suppress corporate social performance [33].

Additionally, under conditions of climate policy uncertainty, enterprises may prioritize short-term financial performance rather than long-term governance goals. This short-sighted behavior can undermine corporate governance performance in the long run [34]. Enterprises may adopt conservative strategies to avoid making significant changes to governance structures and management practices, thereby minimizing potential policy risks. Furthermore, policy uncertainty may result in the insufficient disclosure of governance-related information, affecting transparency and eroding stakeholders' trust. Consequently, improvements in corporate governance performance may be limited.

Thus, climate policy uncertainty suppresses environmental performance, corporate governance performance, and social responsibility performance. Based on this, the first hypothesis of this paper is proposed:

H1: *Climate policy uncertainty has a significant negative impact on corporate ESG performance.*

Climate policy uncertainty refers to the unpredictability in the strictness of regulations, the intensity of rewards and penalties, and the overall policy direction. This uncertainty makes it difficult for investors to assess key factors such as future compliance costs, sustainability, and market supply, leading to a more pessimistic view of investment decisions [35]. Additionally, financial institutions such as banks may adjust their lending policies to mitigate the risks associated with corporate loans, prompting investors to adopt a more cautious approach when selecting investment targets. As a result, enterprises face greater difficulty in securing external funding, thus experiencing higher financial constraints. These financial constraints, in turn, affect corporate ESG performance [27]. Enhancing ESG performance requires substantial investments across various dimensions, such as environmental, social, and corporate governance initiatives. For instance, the adoption of green energy-saving technologies, environmental R&D projects, and employee development programs demands significant corporate resources. However, under financial constraints that limit the available capital, managers are more inclined to prioritize short-term, high-return projects [4] rather than investing in ESG practices. Moreover, financial constraints hinder enterprises' ability to drive new growth through R&D investments, reducing their capacity to fulfill environmental and social responsibilities. This increases the risks of non-compliance with environmental regulations and weakens internal governance, ultimately resulting in poorer ESG performance. Based on this analysis, the following hypothesis is proposed:

H2: *Climate policy uncertainty increases corporate financing constraints, which, in turn, hinders the improvement of corporate ESG performance. Thus, financing constraints play a mediating role in the relationship between climate policy uncertainty and corporate ESG performance.*

Under high climate policy uncertainty, enterprises may prioritize short-term financial performance due to positive market responses, focusing on survival and financial stability [16]. This short-term strategy limits long-term planning and investment in ESG initiatives, thereby suppressing overall ESG performance. Furthermore, in uncertain policy environments, enterprises may opt to meet only the minimum compliance requirements rather than exceeding regulatory standards [36]. Furthermore, in an uncertain policy environment, corporate management may prioritize short-term projects to maintain shareholder confidence or avoid a decline in performance, thereby enhancing short-term financial outcomes at the expense of long-term ESG performance (Clark et al., 2015) [37]. When faced with short-term financial targets, firms are likely to deprioritize improvement projects that require longer time horizons to yield results, channeling resources instead into projects

that promise immediate returns [38]. In terms of resource allocation, firms tend to focus more on areas that directly boost profitability, which suppresses long-term improvements in ESG dimensions [39]. As a consequence, corporate spending on environmental governance decreases, limiting progress in environmental protection and social responsibility. This approach increases short-term financial performance but also reduces investments in environmental initiatives, ultimately hindering improvements in both environmental protection and corporate social responsibility, thereby exerting a negative impact on firms' overall ESG performance (Chen et al., 2022) [16].

In summary, heightened climate policy uncertainty leads enterprises to prioritize short-term financial performance at the cost of long-term investments and improvements in environmental, social responsibility, and governance areas, thereby inhibiting overall ESG performance. Based on this analysis, the following hypothesis is proposed:

H3: *Climate policy uncertainty increases short-term financial performance, which, in turn, hinders the improvement of corporate ESG performance. Thus, short-term financial performance serves as a mediating factor in the relationship between climate policy uncertainty and corporate ESG performance.*

The research framework of this article is shown in Figure 1.

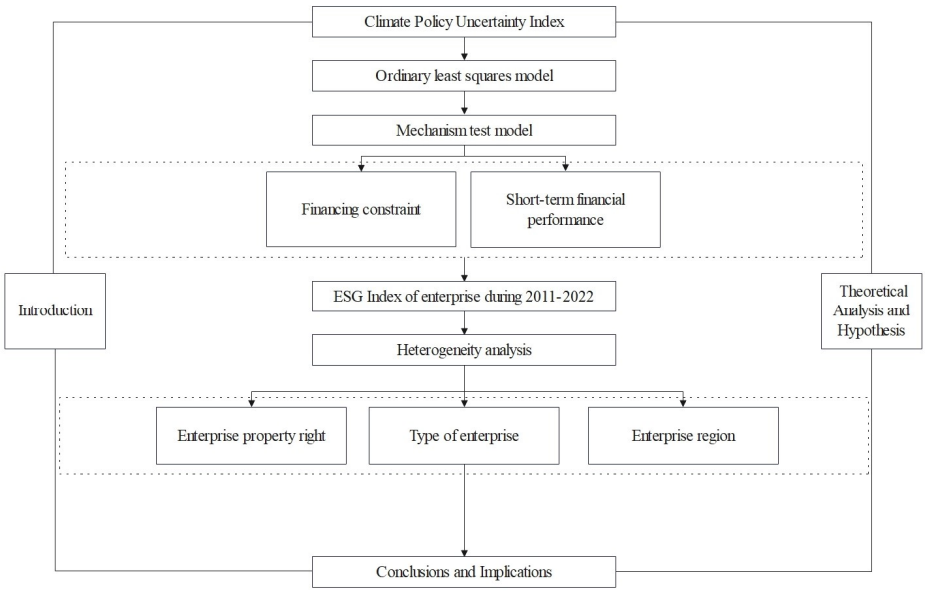

Figure 1. Research framework.

3. Model Setting, Variables, and Data Sources

3.1. Model Setting

To investigate the impact of climate policy uncertainty on corporate ESG performance, the following model is constructed:

$$ESGscore_{it} = \alpha_0 + \alpha_1 CPU_{it} + \sum \alpha_k Control_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

In this model, the subscripts i and t denote the firm and year, respectively. ESG denotes the corporate ESG performance, and CPU represents the Climate Policy Uncertainty Index for the firm during the given period. The coefficient α_1 serves as the principal focus of this study. If α_1 is significantly greater than 0, it suggests that climate policy uncertainty enhances corporate ESG performance. $Control_{it}$ denotes a set of control variables, μ_i captures regional fixed effects, λ_t accounts for time fixed effects, and ε_{it} is the random error term.

Figure 2 illustrates the monthly Climate Policy Uncertainty Index from 2000 to 2022, indicating an overall trend of fluctuating increases. Since policy formulation in China is based on national circumstances, there is a certain time cost involved in the process from policy formulation to dissemination in the media. As a result, there may be a brief lag between major climate events and the formulation of climate policies. The volatility characteristics of the index compiled by Ma et al. reflect this pattern, with peaks in the index corresponding to significant climate events [19], such as the 2009 Copenhagen Summit, the 2011 launch of the carbon emissions trading pilot, the signing of the Paris Agreement in 2016, the 2017 announcement of the U.S. [40] withdrawal from the Paris Agreement, the formal proposal of the "carbon peaking and carbon neutrality" targets in 2020, and the impact of the COVID-19 pandemic in 2020. After converting the monthly index into an annual index through arithmetic averaging and applying logarithmic transformation and winsorization, the Climate Policy Uncertainty Index ranged from 1.296 to 3.354, with increased data stability.

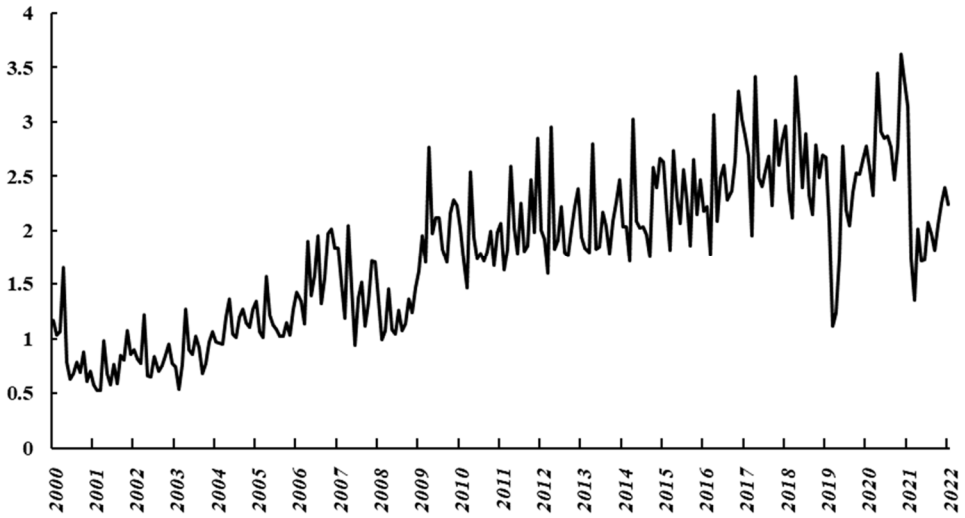

Figure 2. Annual trend of Climate Policy Uncertainty Index from 2009 to 2022.

3.2. Variables

3.2.1. Dependent Variable

ESG ratings, beyond financial performance, represent a comprehensive evaluation of a company's environmental (E), social (S), and governance (G) performance. As stakeholders increasingly focus on corporate sustainability, ESG ratings have garnered growing attention from various sectors. This study adopts the Huazheng ESG performance/rating, which is widely used in previous research, as the quantitative measure of corporate ESG performance (ESG). Compared to other common ratings, such as the Wind ESG performance and SynTao Green Finance's ESG performance, the Huazheng ESG evaluation system not only aligns with the conceptual framework and development experience of ESG but also incorporates the realities of the domestic market, giving it a distinct Chinese characteristic. In practice, this rating has demonstrated superior investment performance and excess returns, further confirming the reliability of the data used in this study. Additionally, the Huazheng ESG evaluation covers all listed enterprises in the Shanghai and Shenzhen A-shares, ensuring data completeness.

3.2.2. Independent Variable

Previous studies have frequently utilized the Climate Policy Uncertainty Index (CPU) developed by Lee and Cho as an explanatory variable to measure climate policy uncertainty. This index is constructed based on the frequency of relevant terms appearing in tweets from authoritative social media platforms, such as Twitter, reflecting the monthly level of climate policy uncertainty as perceived by the media [1]. The construction of the index involves

initially developing a keyword dictionarythat includes synonyms related to climate, policy, and uncertainty, followed by calculating the index using a specified formula.

$$CPU_t = \frac{|(Nc_t \cap Np_t \cap Nu_t)/\sigma_t|}{|Nc_t/\sigma_t|} \quad (2)$$

In the formula, $CPUI_t$ represents the Climate Policy Uncertainty Index for month ttt, with Nc_t, Np_t, and Nu_t denoting the number of Twitter posts containing keywords related to climate, policy, and uncertainty, respectively. $Nc_t \cap Np_t \cap Nu_t$ represents the number of articles containing all three sets of keywords in the same month, and σ_t represents the standard deviation. Following the approach of Ren et al., the monthly Climate Policy Uncertainty Index is averaged arithmetically to derive the annual index, which is subsequently log-transformed after adding 1 [25]. An increase in the index value signifies a higher level of climate policy uncertainty for the corresponding year.

This paper uses the data from Ma et al., which is based on articles published by six major Chinese media outlets: People's Daily, Guangming Daily, Economic Daily, Global Times, and China News Service [19]. By combining manual auditing with the MacBERT machine learning method, this dataset more accurately identifies climate policy uncertainty in media texts, thereby constructing the China Climate Policy Uncertainty Index. The specific formula for calculating the index closely resembles Model (2), with the key distinction that the index is normalized by averaging the values obtained from the six selected newspapers.

3.2.3. Control Variables

Drawing on relevant research, this study accounts for the influence of various corporate development characteristics on ESG performance when selecting control variables. Financial performance and development performance indicators that represent the organizational characteristics of enterprises are included as control variables: firm size (Size), liquidity ratio (Liquidity), debt-paying ability (Icon), financial leverage (Leverage), ownership concentration (OC), investment opportunities (TobinQ), financial expenses (Finance), and the firm's age (Setup). The specific definitions of these variables are shown in Table 1.

Table 1. Main variable symbol definition and calculation method.

Variables	Name	Symbol	Definition
Dependent variable	Enterprise ESG performance	ESG	Huazheng ESG rating
Independent variable	Climate policy uncertainty	CPU	Climate Policy Uncertainty Index of China based on Ma et al. (2023) [19]
Control variables	Solvency	Icon	Asset–liability ratio, total liabilities/total assets
	Enterprise scale	Size	The natural logarithm of a company's total assets
	Current assets ratio	Liquidity	Current assets/total assets
	Operating leverage	Leverage	Financial leverage coefficient
	Ownership concentration	OC	Share sale ratio of top three shareholders (%)
	Investment opportunity	TobinQ	Market capitalization/total assets
	Financial expense	Finance	The expenses incurred by enterprises to raise the funds needed for production, operation, etc., and the measurement index of enterprise financing costs
	Establishment time	Setup	The natural logarithm of the difference between the current year and the year of incorporation is added by 1

3.3. Data Sources

The dependent variable, ESG evaluation data, is obtained from the Huazheng ESG rating platform. The China Climate Policy Uncertainty Index is obtained from Ma et al., published in the journal *Scientific Data*, a Nature sub-journal. Data for other variables are gathered and compiled from the CSMAR database [17]. This study selects 2011–2022 as

the research period based on data availability and comprehensiveness, using listed enterprises on the Shanghai and Shenzhen A-share markets as the full sample. To ensure data completeness and the generalizability of the empirical results, the sample selection and data processing procedures are as follows: (1) exclude ST and ST enterprises; (2) exclude financial enterprises; (3) exclude enterprises with missing core variables; (4) exclude enterprises listed for less than one year; and (5) apply 1% and 99% winsorization to continuous variables to reduce the influence of extreme outliers on the estimation results [41–44]. A total of 26,009 firm-year observations are obtained, covering a broad range of industries. Table 2 reports the descriptive statistics for the core research variables and control variables, showing that the selected indicators hold research significance and empirical feasibility. From the absolute values of ESG performance, there is a considerable variation in ESG performance among enterprises. The mean value of the core explanatory variable, climate policy uncertainty (CPU), is 2.266, which is higher than the median value of 2.227, suggesting that the distribution of climate policy uncertainty is likely right skewed, with most enterprises facing relatively high levels of climate policy uncertainty.

Table 2. Stock screening conditions.

Condition No.	Screening Criteria	Description
1	Exclude ST and ST enterprises	Excludes special treatment (ST) firms that are financially distressed
2	Exclude financial enterprises	Excludes firms in the financial industry to avoid industry-specific effects
3	Exclude enterprises with missing core variables	Removes firms with missing key financial or economic variables
4	Exclude enterprises listed for less than one year; and	Excludes firms that have been publicly traded for less than a year
5	Apply 1% and 99% winsorization to continuous variables	Caps extreme values by winsorizing at the 1st and 99th percentiles to reduce outlier effects

4. Results

4.1. Benchmark Regression

Table 3 reports the baseline regression results examining the impact of climate policy uncertainty on corporate ESG performance. In Column (1), the regression excludes control variables, whereas in Column (2), financial characteristic control variables are incorporated. From the regression results in both columns, it is evident that regardless of whether control variables are included, climate policy uncertainty significantly suppresses corporate ESG performance, thus confirming Hypothesis H1.

Table 3. Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min.	Max.
ESG	26,009	73.35	5.144	58.14	84.46
CPU	26,009	2.266	0.480	1.296	3.354
Icon	26,009	0.428	0.196	0.0560	0.857
Size	26,009	2.298	2.154	0.360	15.23
Liquidity	26,009	1.370	1.040	0	7.653
Leverage	26,009	3.152	0.0540	3.048	3.309
OC	26,009	34.34	15.01	0.286	89.99
TobinQ	26,009	2.019	1.281	0.842	8.083
Finance	26,009	1.634	7.971	−48.45	278.2
Setup	26,009	2.987	0.296	0	4.220

Note: Table 3 presents the summary statistics of the variables used in the analysis. All variables are defined in detail in Table 1.

4.2. Lagged Explanatory Variable

Since corporate behavior operates at the micro-level and does not influence the macro-level formulation and implementation of government climate policies, reverse causality between corporate ESG performance and climate policy uncertainty is weak. To further mitigate potential endogeneity in the model, this paper uses the lagged, single-period Climate Policy Uncertainty Index as the explanatory variable in the baseline regression, with the results presented in Column (1) of Table 4. The results indicate that the lagged Climate Policy Uncertainty Index significantly impacts ESG performance at the 10% significance level. An increase in the Climate Policy Uncertainty Index suppresses corporate ESG performance, consistent with the results when the contemporaneous Climate Policy Uncertainty Index is used as the explanatory variable. These findings demonstrate the robustness of the results.

Table 4. Benchmark regression results.

	(1)	(2)
	ESG	**ESG**
CPU	−0.2290 **	−0.2767 ***
	(0.0996)	(0.0973)
Icon		−4.1817 ***
		(0.4249)
Liquidity		−0.0230
		(0.0297)
Leverage		−0.1569 ***
		(0.0307)
Size		29.9521 ***
		(2.5087)
OC		0.0132 **
		(0.0059)
Tobinq		0.0041
		(0.0364)
Finance		−0.0040
		(0.0092)
Setup		−0.1658
		(0.8876)
Individual fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Constant	73.8587 ***	−18.3501 **
	(0.2259)	(8.0095)
Observations	25,742	25,742
R^2	0.586	0.595

Note: ***, ** represent significance at the 1%, 5% levels, respectively, with standard errors at the individual firm level in parentheses. Unless otherwise specified, subsequent analyses are consistent with the baseline regression.

4.3. Shortening the Time Window

At the end of 2019, the COVID-19 pandemic caused significant disruptions to economic production and daily life, potentially leading to abnormal fluctuations in the sample data. Additionally, given the pandemic's profound impact on the overall economy, data from the pandemic period may not be representative, potentially distorting research on general economic trends. For these reasons, it is necessary to conduct a robustness check by excluding the data from 2020 to 2022, thereby eliminating the influence of this unexpected and unpredictable "black swan" event from the health sector on the reliability of the research results [2,45,46]. The empirical results obtained after narrowing the time window are shown in Column (2) of Table 4. At the 1% confidence level, climate policy uncertainty continues to have a significant negative impact on corporate ESG performance, consistent with the original regression results in both direction and significance. This further con-

firms the robustness of the findings, indicating that the empirical results reflect long-term economic trends and patterns rather than being driven by short-term exceptional events.

4.4. Re-Examination with Additional Fixed Effects

Different industries possess unique characteristics that can influence the ESG performance of enterprises across various sectors, potentially resulting in inherent differences. To ensure the objectivity and accuracy of the research results, this study further controls for industry and city fixed effects, beyond the baseline regression. The results in Column (3) of Table 4 indicate that climate policy uncertainty continues to have a significant negative impact on corporate ESG performance, thereby affirming the robustness of the baseline regression results.

4.5. Changing the Clustering Level

To mitigate the potential issues of heteroscedasticity and autocorrelation in the empirical results, this study uses firm-level clustered standard errors in the baseline regression. However, considering that enterprises within the same region may exhibit similar pollution behaviors and that ESG performance may differ across regions, the regression is re-estimated using clustered standard errors at the provincial level. The results, shown in Column (4) of Table 4, indicate that after increasing the clustering level to the provincial level, the regression coefficient of climate policy uncertainty (CPU) remains significantly negative.

4.6. Replacing the ESG Performance Measure

The baseline regression uses the Huazheng ESG performance measure, while the robustness check, the Huazheng ESG rating, is employed. The Huazheng ESG rating divides corporate ESG performance into nine levels, assigning values from 1 to 9, from lowest to highest. The quarterly ratings are averaged to obtain the annual values, replacing the measure used in the baseline regression for the robustness test. The results in Column (5) of Table 4 show that the coefficient remains significantly negative at the 1% level, consistent with the baseline regression results, further confirming the robustness of the findings.

4.7. Changing the Regression Sample

A statistical analysis of the industry distribution within the full sample reveals that the manufacturing sector accounts for the largest portion, comprising 50% of the sample. Therefore, a subsample of enterprises within the manufacturing industry is selected for re-estimation. The results, shown in Column (6) of Table 4, indicate that climate policy uncertainty continues to have a significantly negative impact on corporate ESG performance, consistent with the baseline regression results. This further confirms the robustness of the baseline findings.

4.8. Instrumental Variable Method

There may be endogeneity issues arising from potential bidirectional causality between climate policy uncertainty and corporate ESG performance. To address this, the study adopts the approach of Ren et al., by using the Global Mean Surface Temperature (GMST) as an instrumental variable [2]. However, the GMST is a macro-level variable, which may present challenges when directly applied as an instrumental variable, particularly in controlling for time and industry effects. Therefore, this study further follows the design logic of the Bartik instrumental variable and constructs an instrumental variable by multiplying the industry-level average of climate change exposure with the GMST. Columns (7) and (8) of Table 4 present the results from the two-stage regression [47]. The first-stage results show that the IV estimate coefficient is 0.1089, significant at the 1% level, indicating a positive correlation between climate policy uncertainty and the instrumental variable. The Kleibergen–Paap rk LM and Cragg–Donald Wald F statistics in the second stage are 21.166 and 44.30, respectively, both exceeding the 10% weak instrument threshold

value of 16.38. Moreover, the second-stage regression results show that climate policy uncertainty continues to suppress corporate ESG performance, further confirming the robustness of the study's conclusions.

5. Mechanism Test Regression

To test Hypotheses H2 and H3, which propose that corporate financing constraints and short-term financial performance mediate the impact of climate policy uncertainty on corporate ESG performance, the following model is constructed:

$$Mediating_{it} = \alpha_0 + \alpha_1 CPUI_{it} + \sum \alpha_k Control_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

In this model, $Mediating_{it}$ represents the mediating variable, which can be either corporate financing constraints or short-term financial performance. To measure corporate financing constraints, index-based methods offer a more comprehensive assessment. Therefore, this paper employs the SA index [48] and the FC index [49] as quantitative indicators of financing constraints. For short-term financial performance, the ROA (Return on Assets) is the ratio of net profit to total assets, while the ROE (Return on Equity) is the ratio of net profit to shareholders' equity, both of which are directly linked to a company's net profit. Since net profit is determined by the company's revenue and costs, changes in policies or market fluctuations that affect a company's revenue and costs will significantly impact the ROA and ROE [50]. Therefore, this study employs the ROA [51,52] and ROE [53] as measurement indicators. Table 5 presents the results of the mediation effect tests for corporate financing constraints and short-term financial performance indicators. Column (1) shows that the regression coefficient of CPU on SA is significantly negative at the 1% level, indicating that as climate policy uncertainty intensifies, the SA index decreases. Since the SA index uses negative values to denote financing constraints (where larger absolute values represent greater constraints), this finding suggests that increased climate policy uncertainty exacerbates financing constraints. Column (2) shows that the regression coefficient of CPU on FC is significantly positive at the 1% level, indicating that as the FC index increases, corporate financing constraints intensify. Together, Columns (1) and (2) demonstrate that climate policy uncertainty deepens corporate financing constraints. Columns (3) and (4) show that the regression coefficients of CPU on the ROA and ROE are significantly positive at the 1% level, indicating that as climate policy uncertainty increases, short-term financial performance improves. Therefore, it can be concluded that climate policy uncertainty enhances corporate short-term financial performance.

Table 5. Robustness tests results.

	(1)	(2)	(3)	(4)
CPU	−0.1851 *	−0.4141 ***	−0.2564 ***	−0.2149 *
	(0.1122)	(0.1069)	(0.0988)	(0.1288)
Control variables	Yes	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	No	No	Yes	No
City fixed effects	No	No	Yes	No
Constant	−16.6258	−2.2114	−19.0823 **	−37.6701 ***
	(10.2160)	(8.2175)	(8.2003)	(4.3830)
Observations	20,462	19,960	25,667	26,008
R^2	0.645	0.591	0.605	0.179

Table 5. *Cont.*

	(5)	(6)	(7)	(8)
CPU	−0.3963 ***	−0.0626 **		−3.6760 **
	(0.1369)	(0.0260)		(1.855)
iv			0.0234 ***	
			(0.1089)	
Control variables	Yes	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Kleibergen–Paap rk LM statistic			21.166 ***	
Cragg–Donald Wald F statistic			44.300 ***	
Constant	−34.0544 ***	−17.9343 ***	—	—
	(12.6609)	(2.6382)		
Observations	12,409	12,409	20,462	20,462
R^2	0.579	0.642	—	—

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively, with standard errors at the individual firm level in parentheses. Unless otherwise specified, subsequent analyses are consistent with the baseline regression.

Simultaneously, when financing constraints lead to limited available capital, managers are more likely to prioritize projects with higher short-term returns rather than investing in ESG practices. Additionally, financing constraints hinder the company's ability to drive new growth through R&D investments, reducing its capacity to fulfill environmental and social responsibilities. This increases the risks of non-compliance with environmental regulations and weakens internal governance, ultimately resulting in poorer ESG performance. Conversely, in the pursuit of short-term financial performance, enterprises may sacrifice long-term investments and improvements in environmental, social, and governance areas, thereby suppressing overall ESG performance.

6. Heterogeneity Analysis

Based on the above discussion, climate policy uncertainty exerts a suppressive effect on corporate ESG performance. However, due to variations in firm characteristics and external environments, this effect may exhibit significant heterogeneity. Therefore, this study examines the heterogeneous impact of climate policy uncertainty on corporate ESG performance from the perspectives of ownership structure, region, and industry.

6.1. Property Right

The inherent connection with the government is a key characteristic of state-owned enterprises (SOEs), influencing their operational decisions and their association with the political system. This connection not only imposes constraints on business operations but also provides SOEs with distinct development advantages. Therefore, it is necessary to conduct an empirical analysis of the heterogeneity in the impact of climate policy uncertainty on corporate ESG performance across different ownership structures [13]. As shown in Columns (1) and (2) of Table 6, for non-state-owned enterprises (non-SOEs), climate policy uncertainty significantly affects ESG performance at the 1% level, whereas for SOEs, the effect is not significant. The possible reasons are as follows: Firstly, in the context of unpredictable climate policy changes, non-state-owned enterprises (non-SOEs) face inherent disadvantages compared to state-owned enterprises (SOEs) in accessing policy-related information. This disadvantage often hinders their ability to accurately perceive policy shifts and integrate climate change considerations into their long-term strategic planning, thereby increasing their operational risks and sensitivity to climate policy uncertainty. Such a disadvantage further exacerbates the financing constraints faced by non-SOEs [54–56]. Additionally, unlike SOEs, non-SOEs do not possess an advantage in securing government support or attracting external investments. Consequently, non-SOEs find it more challenging to obtain the necessary resources, such as funding and technology,

to enhance their ESG performance [57,58]. This lack of support intensifies the suppressive effect of policy uncertainty on their ESG-related initiatives.

Table 6. Mechanism test regression results.

	SA	FC	ROA	ROE
	(1)	(2)	(3)	(4)
CPU	−0.0043 **	0.0048 *	0.0018 **	0.0062 ***
	(0.0017)	(0.0026)	(0.0009)	(0.0019)
Control variables	Yes	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Constant	−4.0889 ***	13.7228 ***	−0.5773 ***	−1.3282 ***
	(0.2779)	(0.2877)	(0.0823)	(0.2195)
Observations	25,742	25,742	25,742	25,713
R^2	0.971	0.913	0.607	0.456

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively, with standard errors at the individual firm level in parentheses. Unless otherwise specified, subsequent analyses are consistent with the baseline regression.

6.2. Region

Due to the regional differences in industrial distribution, economic development levels, and policy coverage in China, the perception and response to climate policy uncertainty are influenced by the geographical location of enterprises. This results in regional heterogeneity in the impact of climate policy uncertainty on corporate ESG performance. Referring to previous studies on regional heterogeneity, the sample enterprises are divided into three regions—eastern, central, and western—based on their respective provinces for the regression analysis [59]. As shown in Columns (3) to (5) of Table 6, climate policy uncertainty has a significant negative impact on the ESG performance of enterprises in the eastern region, while its effect on enterprises in the central and western regions is not significant. The reasons for this disparity may include the following: First, compared to the central and western regions, the eastern region exhibits more mature economic development and stricter policy enforcement, making firms in this region more sensitive to policy fluctuations [60]. Second, the higher environmental standards and policy requirements in the eastern region compel firms to maintain their market competitiveness through technological upgrades and management innovation [61,62]. Consequently, firms in the eastern region face greater pressure for environmental protection and technological advancement, making them more susceptible to the impacts of climate policy uncertainty.

6.3. Industry

Different industries exhibit significant variations in production methods and factors of production, leading to distinct sensitivities to changes in climate policies. Therefore, it is necessary to analyze the industry-level heterogeneity in the impact of climate policy uncertainty on corporate ESG performance [25]. This study adopts the industry classification framework from Ren et al. (2022) for the empirical analysis of heterogeneity; this study classifies the sample enterprises into four major industries: capital intensive, labor intensive, technology intensive, and energy intensive. The aim is to examine industry heterogeneity in the impact of climate policy uncertainty on corporate ESG performance [2]. The regression results are presented in Columns (6) to (9) of Table 7. For enterprises in the technology-intensive industries, climate policy uncertainty has a significant suppressive effect on ESG performance, while for enterprises in labor-, capital-, and energy-intensive industries, the impact is not significant.

Table 7. Heterogeneity analysis results.

	SOEs	Non-SOEs	Eastern	Central	Western
	(1)	(2)	(3)	(4)	(5)
CPU	0.1142	−0.4368 ***	−0.5748 ***	−0.2100	−0.3013
	(0.1185)	(0.0909)	(0.1190)	(0.2485)	(0.3091)
Control variables	Yes	Yes	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	−37.8509 ***	−22.4987 ***	−14.7748	−44.7847 **	−24.5972
	(6.1394)	(5.8099)	(9.7505)	(20.9365)	(20.2389)
Observations	9896	16,108	18,657	3595	3490
R^2	0.282	0.151	0.596	0.579	0.606
	Labor	**Capital**	**Technology**	**Energy**	
	(6)	(7)	(8)	(9)	
CPU	−0.2923	−0.0862	−0.3419 **	−0.0333	
	(0.1847)	(0.3046)	(0.1410)	(0.2346)	
Control variables	Yes	Yes	Yes	Yes	
Individual fixed effects	Yes	Yes	Yes	Yes	
Year fixed effects	Yes	Yes	Yes	Yes	
Constant	−0.1576	−60.9513 *	−32.1023 **	−15.8364	
	(14.7022)	(32.2018)	(13.3330)	(18.5702)	
Observations	7649	2231	11,487	4243	
R^2	0.616	0.664	0.602	0.576	

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively, with standard errors at the individual firm level in parentheses. Unless otherwise specified, subsequent analyses are consistent with the baseline regression.

The primary reasons may be as follows: First, technology-intensive firms typically rely on long-term and stable R&D investments to maintain their competitive advantage. However, climate policy uncertainty makes it difficult for these firms to predict the direction of R&D investments, thereby increasing investment risks. As a result, technology-intensive firms often postpone R&D projects, ultimately affecting their competitive edge [63,64]. This leads to potential risks, such as the incorrect selection of technological paths and uncertainty in R&D investment returns, which, in turn, impact their long-term competitiveness and sustainable development capabilities. Second, climate policy uncertainty also affects market demand to some extent. Frequent changes in climate policies may result in shifting compliance requirements and evolving market demands. For technology-intensive firms, this necessitates the continuous redefinition and adjustment of their product designs and market positioning to adapt to new market demands and changes. Consequently, the increased cost of compliance for these firms heightens operational risks [65,66].

7. Conclusions and Implications

7.1. Research Conclusions

This study focuses on A-share-listed enterprises and uses panel data from 2011 to 2022, including Huazheng ESG performance, the Climate Policy Uncertainty Index, and publicly disclosed financial information to examine the impact of climate policy uncertainty on corporate ESG performance. Additionally, the study empirically analyzes the transmission mechanisms through which climate policy uncertainty affects ESG performance. Finally, the heterogeneity of the baseline regression results is assessed under varying conditions of corporate ownership and industry attributes. The main conclusions of the study are as follows:

(1) Previous research has primarily focused on the impact of policy uncertainty on corporate green development. In contrast, this study uses corporate ESG performance as a quantitative measure of corporate sustainable development. The findings reveal that policy

uncertainty, stemming from ambiguity in the enactment, enforcement strength, and the scope of climate policies, inhibits improvements in corporate ESG performance.

(2) Unlike previous studies that primarily focused on the direct impact of policy uncertainty on corporate outcomes, this study conducts an in-depth analysis of the underlying mechanisms. The transmission mechanism through which climate policy uncertainty suppresses ESG performance is the pathway of "climate policy uncertainty–corporate financing constraints/short-term financial performance–corporate ESG performance." The mediating effect of financing constraints manifests as climate policy uncertainty dampening investor enthusiasm, increasing corporate financing constraints, and reducing the funds available for enhancing ESG performance, thereby inhibiting its improvement. Simultaneously, in an uncertain policy environment, corporate management may focus more on short-term financial goals to ensure the survival and financial stability of the company. This short-sighted strategy limits long-term ESG planning and investment, further suppressing ESG performance.

(3) Different types of enterprises have varying sensitivities to climate policy changes. Climate policy uncertainty has a negative impact on the ESG performance of non-state-owned enterprises. Additionally, climate policy uncertainty suppresses the ESG performance of enterprises in technology-intensive industries. Furthermore, the impact of climate policy uncertainty on the ESG performance of enterprises in the eastern region is also negative.

This study has certain limitations. First, it primarily focuses on the context of climate policy uncertainty in China, without adequately considering the significant differences in policy environments and regulatory frameworks between countries, which may lead to varying impacts on corporate ESG performance. Therefore, future research should attempt cross-country comparisons to explore differences in corporate ESG performance under diverse policy environments. Lastly, this study employs panel regression models based on historical data, which may have limitations in capturing the long-term causal effects of climate policy uncertainty. Future research could consider using longitudinal case studies or natural experiments to further investigate the long-term factors and mechanisms affecting corporate ESG performance.

7.2. Policy Recommendations

First, the government can actively take measures to reduce corporate perceptions of climate policy uncertainty. On the one hand, there is a need to establish climate policies that are both long-term and stable while preserving flexibility in the implementation. This requires authorities to enhance the foresight in assessing climate risks and the risks of assuming climate responsibilities. When formulating climate policies, they should comprehensively consider the occurrence patterns of extreme weather events, future domestic climate goals, and policy directions, thereby minimizing the frequency of subsequent policy changes through more detailed and thorough early-stage planning. Additionally, involving enterprises in the policy-making process and gathering feedback from them as the ultimate implementers of climate policy would help ensure that the policies are grounded in reality and meet actual needs, thus reducing the likelihood of adjustments during implementation. On the other hand, reducing information asymmetry between enterprises, investors, and the government is critical. Leveraging the role of the media in disseminating and promoting policy information—while maintaining national security and not interfering with governmental duties—can help businesses develop more targeted strategies in response.

Second, efforts should be made to "soften" the impact of climate policy changes on enterprises. Reasonable fallback policies should be developed, such as providing transitional subsidies for energy-intensive enterprises during the implementation of new policies to help them navigate periods of fiscal tightening caused by policy changes. This also allows for a buffer period for their transition to green development, thereby reducing the shock they face. Furthermore, supplementary supportive policies can be introduced for new regulations. For instance, for enterprises pursuing green transformation, financial

support can be increased through green finance, and long-term sustainable growth can be fostered by providing environmental technologies and skilled personnel.

Third, policy implementation should be tailored to local conditions and industry specifics, striking a balance between rigidity and flexibility. In recent years, as awareness of sustainable development has grown across various sectors, mandatory measures aimed at achieving climate change mitigation goals have been introduced and enforced. However, during the policy formulation process, full due diligence cannot always be conducted, resulting in the issuance and implementation of "one-size-fits-all" policies. Factors such as regional development differences, industry-specific characteristics, corporate technological disparities, and varying capacities to bear reform costs all affect the feasibility and effectiveness of policy implementation. Based on the heterogeneity analysis, different types of enterprises exhibit varying sensitivities to climate policy changes. Protective and incentivizing climate policies should be more inclined toward non-state-owned enterprises, non-technology-intensive industries, and enterprises in central and western regions, which are more vulnerable and in need of transformation. Increasing regulatory flexibility for these enterprises will allow green transformation and economic development to proceed in harmony.

Author Contributions: Conceptualization, Z.Z.; methodology, L.C. and Z.Z.; software, Y.F.; formal analysis, Z.Z., Y.F. and Z.Z.; resources, Y.F. and Z.Z.; writing—original draft preparation, H.Z. and Y.F.; writing—review and editing, Z.Z. and H.Z.; visualization, Y.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Social Science Foundation of China (Research on the multi-dimensional measurement and improvement path of the resilience of the agricultural industry chain under the impact of climate change, Project No. 24CTJ030), Statistical Research Project of the National Bureau of Statistics (Research on Statistical Measurement and Driving Mechanisms of China's Green Economic Transformation, Project No. 2024LD002),and Changsha Natural Science Foundation Project (Statistical Monitoring and Evaluation Research on Comprehensive Green Transformation of Economic and Social Development under the Carbon Peak Target, Project No. kq2208048).

Data Availability Statement: The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request. The data are not publicly available due to our need for further research utilization of this data and the potential for increased publication opportunities by retaining it.

Conflicts of Interest: The authors declare no conflicts of interest.

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