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The Impact of Economic Policy Uncertainty on Enterprise Green Innovation: A Study on the Moderating Effect of Carbon Information Disclosure

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Abstract: In the context of achieving carbon peaking and carbon neutrality, China has introduced a series of policies to encourage enterprises to adopt green innovation behavior. However, enterprises are faced with an uncertain policy environment surrounding green innovation decision-making; the mechanisms that influence these decisions are poorly understood; and the regulatory role of carbon information disclosure quality against the background of the dual carbon goals is unclear. We found that the increase in economic policy uncertainty is not conducive to enterprises' decision-making on green innovation. However, an increase in the quality of carbon information disclosure can promote green innovation in enterprises. Additionally, the quality of carbon information disclosure plays a moderating role in economic policy uncertainty and corporate green innovation. Enterprises can mitigate the negative impact of economic policy uncertainty on corporate green innovation by ensuring high-quality carbon information disclosure to adapt to national policies and improve the level of innovation.

Keywords: economic policy uncertainty; enterprise green innovation; carbon information disclosure

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1. Introduction

In 2014, Chinese President Xi Jinping presented the idea of a new normal economy during the Asia-Pacific Economic Cooperation (APEC) summit [1] and high-energy-consuming industries. Under the new normal, the model focuses on four goals: service, innovation, equity, and sustainability [2]. China is under considerable stress to strengthen its economy and increase its productivity while also ensuring environmental sustainability. Therefore, the contradiction between economic growth, energy use, and environmental conservation is serious, which will threaten Chinese economic sustainability unless these aspects are addressed and balanced.

As China's economy has entered the new normal, the pressure to transform enterprises has increased, and enterprise innovation has become the force driving economic development. Only by innovating can enterprises promote sustainable economic development. With the introduction of policies such as carbon pricing and carbon neutrality, green technology innovation (GTI) has become an important means for enterprises to respond to national policies. As the main participants in green innovation, enterprises need to actively try to transform green technology into production for various applications. However, the academic community has expressed considerable concern about the enterprise sector's propensity to innovate through green methods and its specific actions. Businesses must include environmental preservation and sustainable development in their development strategies, given the intense policy pressure and ethical limitations. Green innovation is groundbreaking and beneficial to the environment and general welfare, but it also carries serious risks and causes erratic effects on business profitability. As a result, enterprises' internal capacity for green innovation is limited, but external environmental rules and other

policies are encouraging firms to change and advance in the direction of green innovation. According to academics, economic policy uncertainty (EPU) has both positive and negative effects on enterprise green innovation. Xin Cui used a sample of Chinese A-share listed firms from 2005 to 2019 and found strong evidence that EPU is significantly and negatively associated with enterprise green innovation [3]. The results of the analysis on the moderating effects showed that environmental subsidies from governments can substantially mitigate the negative EPU effect on enterprise green innovation, whereas financial constraints exacerbate the negative impact of the EPU. Yang X. reported that uncertainty is the source of enterprise innovation and found that EPU has a slight promoting effect on the GTI of Chinese-listed enterprises by taking Chinese A-share listed companies from 2010 to 2018 as the study sample [4]. Enterprise ownership and industry characteristics can also affect the result. EPU has a stronger promoting effect on the GTI activities of state-owned and high-tech enterprises than on those of common enterprises. In particular, the GTI of high-polluting enterprises has a weaker incentive effect than that of ordinary enterprises when EPU is higher. This can be explained by the fact that state-owned enterprises have more-implicit capital guarantees, whereas high-tech enterprises have stronger motivation to innovate, and the high-polluting enterprises are more dependent on traditional production equipment [5].

To ensure corporate green innovation, China has implemented several policies. The question whether the implementation of these measures to address the strategic context has contributed to fostering corporate innovation or whether the "good intentions" have had side effects is worth debating. One of these is the disclosure of carbon information, which, as a notable dual-carbon-goal influencer, strongly impacts how businesses decide to innovate in the green sector. Additionally, it offers businesses a fresh viewpoint on how to navigate the uncertain economic policy landscape while engaging in green innovation.

2. Literature Review

The study findings of domestic and international studies on corporate green innovation currently provide a reference for boosting the green innovation capability of businesses and fostering economic growth. According to Reid and Miedzinski's hypothesis, corporate green innovation successfully combines ecological and economic innovation, serving as a valuable symbiosis that can effectively increase both ecological and economic efficiency. Thus, we defined "green enterprise innovation" as a motivation for green growth, which is key to controlling the worsening of environmental degradation and guaranteeing the sustained growth of a company's economy activities [6]. Green innovation consists of green product innovation and green process innovation. Environmental rules and corporate governance impact green innovation, with a number of competitive benefits and improved commercial viability [7]. Among the drivers of green innovation are environmental rules, technical competence, management environment care, competition constraints, and customer demand for green products [8]. According to some researchers, supply, demand, and policy regulation are the main drivers of green innovation. In this study, we focused on an analysis on EPU, and the total effects of carbon disclosure were divided into two categories: political and regulatory. Stringent environmental regulations affect how corporate ecological responsibility is implemented and encourage corporate green innovation [9,10]. According to Li Qingyuan et al., who used the industries with the worst pollution levels on the A-share listed stock market as their study subject, businesses face higher production costs because of stringent environmental regulations, which prevent them from innovating in the green sector. The findings of these studies demonstrate that more in-depth research is still needed on the precise factors that influence corporate green innovation, particularly when considering economic policy uncertainty and carbon information disclosure in environmental regulation.

Economic policy uncertainty (EPU) changes the business environment and weakens the ability of companies to anticipate the timing, content, and potential effects of policy execution [11]. Although some evidence has shown that EPU is theoretically related to en-

terprise environmental innovation, no clear empirical findings are available yet. According to the expectations of real option theory, when confronted with uncertain variables, enterprises take a wait-and-see approach and delay investing in innovation [12], as innovation is linked to a large amount of capital, a lengthy period of investment, and a high level of irreversibility [13]. Firms may presume that achieving sustainable development will be difficult without innovation under high EPU. In such circumstances, companies will be able to concentrate on the competitiveness of environmental innovation and will probably be able to improve their environmental performance when EPU is high. Because of the lack of environmental protection, resource and environmental constraints are becoming increasingly problematic in China. Theoretically, macrocontrolling government policies encourage business innovation in green technologies and related economic growth, but the problem caused by uncertain economic policies also arises from the frequent regulation of macro policies.

The uncertainty resulting from the unclear direction and scope of policies pertaining to the operation and output of businesses is referred to as economic policy uncertainty. To attain the dual objectives of carbon peaking and carbon neutrality, the state has developed a number of measures that have helped some environmentally friendly businesses to grow. However, these measures have also posed additional difficulties and increased uncertainty for businesses' use of green innovation. Theoretically, the macrocontrol of government policies encourages green innovation in businesses and corresponding economic development, but numerous studies conducted abroad have demonstrated that policy changes impact green innovation in businesses. The management of innovation behavior and macropolicy adjustment are strongly related, as are decision-making and policy trends. As a result, policies and changes impact enterprise management, which then impacts enterprises' expectations for system risk, which impacts enterprises' green innovation behavior [13].

Green innovation is a type of uncertainty in which investment activities are irreversible, so policy changes may result in a serious loss for an enterprise [8], which then impedes the green innovation of the enterprise. Economic policy uncertainty also impacts the company cost of capital and the entire research and development, production, and manufacturing chain. In some situations, enterprises fear uncertainty more than policy, which can impede innovation. However, uncertainty can be a source of enterprise innovation [4]. To increase investment in green innovation, some academics have contended that businesses should focus more on prospects and possible rewards in uncertain times [14–17]. As a result of China's goals to attain carbon peaking and carbon neutrality, the number of policy changes to pertinent environmental rules will increase. Therefore, we must study how businesses make decisions in the face of such economic policy uncertainties and especially how corporate green innovation is impacted. Therefore, companies have key roles to play in green innovation to achieve sustainable development in China. Finally, emerging markets must innovate to protect the environment. The Chinese experience with green innovation is a key example for other development-centric economies [5].

The quality of carbon information disclosure also influences how well businesses develop. Carbon information disclosure serves as a conduit between businesses and the outside world. An enterprise's decision to disclose carbon information is important, and the system that the enterprise has in place contributes to the capital market's continued smooth operation. Since the early 2010s, the number of enterprises that voluntarily disclose their environmental information has substantially increased. However, the increase in environmental disclosure has also been accompanied by social doubts about the veracity of the information. In many nations, the level of information disclosure by listed companies has long been the center of attention. Many developed countries have successively established relatively complete carbon information disclosure regulations, including the climate-related financial information disclosure (TCFD) task force and the Carbon Disclosure Project (CDP) [16]. However, China's system for disclosing carbon information was implemented later and was based largely on the CDP. To control pollution and improve

the environment, China has implemented a series of environmental regulations, including command-and-control and market-based regulations. In recent years, the Chinese government has begun to pay more attention to information disclosure and framed regulations in this respect. On 1 May 2008, the Measures on Open Environmental Information (Trial) were made operational, which helped change the role of the Chinese regulators from maintaining traditional government-led environmental supervision to encouraging information sharing and voluntary reductions. In 2008, two professional environmental nongovernmental organizations, the Institute of Public and Environmental Affairs (IPE) and the Natural Resources Defense Council (NRDC), jointly published the pollution information transparency index (PITI) to evaluate the degree of pollution information transparency in 113 prefecture-level cities in China. The remaining cities were not included in the PITI list. A city on the PITI list must release more information on pollution sources; the public in a PITI city can easily access environmental information, have high environmental awareness, and further participate in public action, thereby creating pressure for stricter regulations on high-polluting industries and firms [17]. However, issues remain with partial disclosure, nondisclosure, or incorrect information disclosure in businesses. Companies that implement green innovation typically face financial constraints because this hinders them from quickly generating profits and improving management performance. As a result, management is reluctant to implement green innovation because it requires long-term sustained investment. Agency issues can be considerably mitigated by increasing the level of carbon information disclosure and information transparency [18]. Additionally, enhancing the quality of carbon information disclosure can ease business finance constraints [19]. The quality of carbon information disclosure and corporate green innovation are closely related, as shown in the information above, but more research is needed to determine how these two factors interact to create economic policy uncertainty.

At present, China is increasingly paying attention to the environment and hopes to promote the green innovation of enterprises through a series of policies. Therefore, we should discuss whether the policy changes have played roles in promoting green innovation. Carbon information disclosure is a constraint and a requirement for enterprises against the background of achieving carbon peaking and carbon neutrality. Additionally, thanks to the special nature of business entities, enterprises with high and low carbon information disclosure levels are different in terms of their ability to deal with uncertain environments. Thus, we should also study and discuss whether the carbon information disclosure level of enterprises affects the effects of economic policy uncertainty on enterprises' green innovation input.

Different studies have been conducted on the relationships between green innovation and corporate performance. Traditionally, a contradiction has been thought to exist between green innovation and corporate performance, where companies' pursuit of green innovation adds to their costs and pools their resources [20]. According to the point of view of the review, which takes Potter as its representative, green innovation and business performance can coexist and contribute to higher productivity and lower costs. Thus, companies should gather their resources and capacity to foster their own green innovative behavior [21], products, and process innovation and to contribute to their acquisition of environmental benefits and competitiveness. Green innovation can lower the manufacturing costs of firms and improve the performance of firms in the areas of environmental and technological innovation [22,23]. According to the above discussion, economic policy and enterprises need to be further studied in conjunction with green innovation. The degree to which various enterprises disclose their carbon footprints in response to economic policy uncertainty regarding green innovation may differ; carbon disclosure levels in the relationship between the two urgently need to be validated [24]. We further examined economic policy uncertainty, carbon disclosure, and the relationships between and among enterprises engaged in green innovation, including the green innovation of the enterprises under economic policy uncertainty, carbon disclosure, the relationship between the corporations engaged in

green innovation. We also explored the information disclosure levels of different companies engaged in green innovation [25–27].

3. Research Hypotheses

3.1. Economic Policy Uncertainty and Enterprise Green Innovation

Enterprise green innovation is an investment strategy that makes use of internal finances and resources for product creation, process improvement, and other activities to create the company's distinctive core competitiveness and achieve the appropriate strategic goals. Therefore, the process of how uncertainty produced by policy changes affects enterprise investment is bound to have an impact on enterprise R&D investment, as well as on the green innovation of enterprises [28]. Real option theory, asymmetric information theory, signaling theory, and other theories on the link between the two are covered in the sections that follow.

According to real option theory, a business will wait for value to increase, and management will decide to wait until a policy is stable and the environment is clear before making decisions when the decision-making environment of the enterprise becomes uncertain owing to policy changes. In the case of an emergency created by uncertain economic policy, businesses keep cash on hand to balance present investments with future expenditures. Real options are based on the idea that investments are irreversible, which explains how uncertainty affects investments [29]. From the theoretical research in the pertinent literature, corporate green innovation is substantially irreversible; hence, we can argue that corporate green innovation is constrained by the unpredictability of economic policy.

According to asymmetric information theory, the difficulties that external stakeholders face in overseeing management worsens as economic policy uncertainty rises. In addition, owing to poor informational communication, external investors will find it challenging to assess the state of businesses in an environment with high economic policy uncertainty [30]. This will exacerbate businesses' financial constraints, obstruct R&D funding, and prevent businesses from pursuing green innovation.

Some academics have contended that uncertainty encourages green innovation among businesses by encouraging them to act in ways that support it. Changes in policy have varied effects on green innovation because, innovation investment is different from conventional investment. Enterprises typically rely on innovation to increase their market influence because of escalating competition and the presence of dangers. Competition intensifies in an environment of increased economic policy uncertainty, and businesses turn to innovation as a method to manage this uncertainty. Through innovation, businesses can quickly occupy the market and achieve profits [31]. As a result, innovation has emerged as a viable strategy for businesses to obtain profits in a volatile environment, which is the natural result of uncertain economic policies. In summary, the following hypotheses were advanced in this study:

Hypothesis 1a (H1a). *Corporate green innovation and economic policy uncertainty are negatively related.*

Hypothesis 1b (H1b). *Corporate green innovation and economic policy uncertainty are positively related.*

3.2. Carbon Information Disclosure and Enterprise Green Innovation

The concept of asymmetric information indicates that the insufficient transfer of information between two parties results in a condition of information asymmetry, which creates a barrier to the flow of capital between the two parties. According to signaling theory, raising the level of information disclosure for carbon emissions can increase information transparency, substantially lessen the information gap between internal and external businesses, foster stakeholder relationships, and encourage corporate green innovation. The level of the disclosure of carbon information can be increased to help shareholders monitor management, understand the business's status, and foster innovation.

In accordance with a signaling theory analysis, the greater the disclosure of carbon information, the better the external investors or creditors understand the company's situation, the less information asymmetry will exist between the two parties investing in the company's innovation, and the lower the risk. Conversely, stockholders can be provided with additional information on the company's situation. Both encourage green invention. In summary, the following hypothesis was advanced in this study:

Hypothesis 2 (H2). *Corporate green innovation is favorably connected with the caliber of carbon information disclosure.*

3.3. Economic Policy Uncertainty, Carbon Information Disclosure, and Enterprise Green Innovation

Policy uncertainty has a negative impact on corporate green innovation in H1a. The signal transmission idea states that the publication of carbon information is a signal transmission technique. Asymmetric information's negative consequences can be reduced through carbon information disclosure. Businesses with high-quality, standardized carbon information disclosure can ease their financial limitations by minimizing information asymmetry, thereby lessening the adverse impact of unclear economic policies on their green innovation.

If corporate green innovation and economic policy uncertainty are positively correlated, per H1b, when economic policy uncertainty is severe and the level of carbon disclosure is high, management should be more eager to convey the company's sound financial position and ability to resolve proxy conflicts to help the business to create favorable internal and external environments that will encourage green innovation. Uncertainty in economic policies has a selection effect on corporate green innovation [32]. Thanks to the advantages listed above, businesses with high levels of carbon information disclosure can quickly leverage uncertainty to create opportunities and advance their own development through corporate green innovation.

In summary, we advanced the following opposing hypotheses:

Hypothesis 3a (H3a). *The level of carbon information disclosure moderates the relationship between corporate green innovation and economic policy uncertainty, and the negative correlation between the two is weaker for companies with high levels of carbon information disclosure than it is for companies with lower levels.*

Hypothesis 3b (H3b). *The level of carbon information disclosure influences the relationship between uncertainty in economic policy and corporate green innovation, and enterprises with high levels of carbon information disclosure have a stronger positive relationship between economic policy uncertainty and corporate green innovation than enterprises with low levels of carbon information disclosure.*

4. Study Design

4.1. Data Source

Using data from 2010 to 2019, we chose A-share corporations on the Shenzhen Stock Exchange as the sample companies. The exclusion criteria included financial firms, businesses with operational irregularities (PT, ST, or delisting) during the observation period, and businesses with egregiously inaccurate data on key factors.

The basic financial and business information from the sample companies, including enterprise size, listed years, investment opportunities, return on equity, operating revenue growth rate, asset–liability ratio, cash flow ratio, and variables of carbon information disclosure level, were analyzed in the empirical study. We used databases maintained by CSMAR and Guotai, annual company reports, social responsibility reports, the website of the Shenzhen Stock Exchange, and manual collation. The Economic Policy Uncertainty

Index created by Professors Nick Bloom, Scott R. Aker, and Steven J. Davis was mainly used. Following the procedure, the 8637 unbalanced panel data of 1613 sample companies were retrieved.

4.2. Declaration of Variables

4.2.1. Measurement of Economic Policy Uncertainty

The Economic Policy Uncertainty Index is widely used as the primary tool for assessing the unpredictability of economic policy. The annual data of the index are used to match the explanatory and control variables. Thanks to the index's monthly publications, monthly values can be averaged to calculate the yearly EPU, which is the yearly economic policy uncertainty. Have all used this index in their studies, showing that it is a reliable method of measuring uncertainty in China's economic policy [32–34].

4.2.2. Measurement of Carbon Disclosure

The strategy, system, action, and effect layers of the carbon information disclosure quality evaluation system developed in this study are based on the evaluation standards of international authoritative organizations on enterprise carbon information disclosure. The strategic layer includes climate situation awareness and carbon-emission-reduction strategies. The system layer involves the creation of systems for the disclosure of carbon information and for reducing carbon emissions; the action layer includes the disclosure of carbon information in action and the promotion of reducing carbon emissions, among other things. The emission of "three wastes" (wasted water, wasted gas, and wasted residue), the emission-compliance rate, and the reduction in carbon emissions all factor into the effective level. The criteria for scoring included the following: (1) importance—annual report score 1 and social responsibility report score 2; quantification—zero points for no disclosure, one point for a simple description, and two points for a quantitative description.

4.2.3. Measurement of Enterprise Green Innovation

The studies on corporate green innovation are relatively abundant in number, and other measurement indicators have been used, such as R&D investment, the number of patent applications, and the number of new products [35]. Among them, the number of patent applications has often been used to measure the green innovation of enterprises' accounts, but Yang Yang pointed out certain shortcomings in measuring the level of enterprise innovation in China [36]. First, China's awareness of patent protection is weak, and the number and situation of patent applications cannot fully reflect the degree of corporate innovation. In addition, the aim of most corporate innovation behaviors is to enhance the competitiveness of enterprises, so most of the enterprise innovation behaviors require confidentiality. Thus, a large part of enterprise innovation behavior cannot be reflected in the application for patents, and enterprise green innovation is a kind of enterprise innovation behavior [37]. Similarly, green innovation achievements can only lead to fewer patents; using the number of patents only to measure the level of enterprise green innovation will lead to an underestimation of this indicator. The number of new products as an indicator is also subject to the same inaccuracies as the number of patents.

Therefore, we used the level of R&D investment to measure the level of green innovation of enterprises. An enterprise's R&D expenditure reflects the resources invested by the enterprise in innovative product development and maintenance; in general, the more an enterprise invests in R&D, the more innovation it will achieve. As a kind of enterprise innovation behavior, enterprise green innovation also has such a nature and logic. Accordingly, we selected the R&D investment related to green, clean, environmental governance; environmental protection; energy savings; etc. as the amount of enterprise green innovation investment from the enterprise R&D summary table. We used the ratio of the total corporate green R&D investment to enterprise operating income that was used by [38], that is, the value of R&D investment intensity, to express corporate green innovation. We here refer to the research method adopted by [39], where an enterprise's total

investment in green R&D was used to measure its investment in green innovation, and the number of patent applications related to green innovation was used as a robustness test.

4.2.4. Measurement of Control Variables

In regression, the influence of the control variable on the dependent variable should be controlled to finally obtain the causal relationship between the independent and dependent variables. In this study, we referred mainly to the research on the factors influencing the green innovation of domestic and foreign enterprises to select the appropriate control variables. We also drew on the research models of Zhang Wanli, Wang Xinhong, Kong Dongmin, Li Huiyun, and Gulen and Ion to select the control variables on the basis of two aspects [8,40–43]. The first was based on the enterprise control variables, including the company's size, listing years, property rights, investment opportunities, operating cash flow, debt ratio, sales growth rate, and return on net assets (ROE), as basic information and corporate financial variables. The second aspect involved regional characteristic control variables, which included mainly the GDP growth rate, foreign participation (foreign direct investment, or FDI), and area situation (Table 1).

Table 1. Variables and measurement methods.

Variable Type	Variable	Symbol	Variable Measurement Method
Explained	Enterprise green innovation	EGI	Value of investment in enterprise green innovation/enterprise operating income
Explanatory	Economic policy uncertainty	EPU	Internationally used index of economic policy uncertainty, measured as monthly arithmetic average
Regulated	Carbon information disclosure	CDI	By referring to the evaluation system of the Climate Change Disclosure Guidelines, scored 1–4
Control variables	Scale of company	Size	Take natural logarithm of total assets at year end
	Nature of property rights	Prty	State-owned enterprises: Prty = 1; otherwise, Prty = 0
	Asset–liability ratio	Lev	Lev = year-end liabilities/year-end total assets
	Operational cash flow	CF	CF = net operating cash flow/total assets at year-end
	Listed years	Age	Age = present year minus year of listing +1
	Investment opportunities	Tz	Tz = market value/total assets at year end
	Growth rate of *GDP*	*GDP*	$GDP = \frac{GDP_t - GDP_{t-1}}{GDP_{t-1}}$
	Return on equity	ROE	ROE = net profit/net asset at year end
	Growth rate of sales	*Sg*	$Sg = \frac{Sg_t - Sg_{t-1}}{Sg_{t-1}}$
	Foreign participation	FDI	Foreign direct investment/gross local product
	Area situation	Area	Eastern area: Area = 1; otherwise, Area = 0

4.3. Model Construction and Empirical Techniques

To verify the impact of economic policy uncertainty and carbon information disclosure on corporate green innovation, the models were constructed as follows:

$$EGI_{i,t} = \alpha_0 + \alpha_1 EPU_{i,t-1} + \sum \alpha_k Control\ Variables + \lambda_i + \mu_i + \varepsilon_{i,t} \quad (1)$$

$$EGI_{i,t} = \beta_0 + \beta_1 CDI_{i,t-1} + \sum \beta_k Control\ Variables + \lambda_i + \mu_i + \varepsilon_{i,t} \quad (2)$$

where $EGI_{i,t}$ represents the green innovation level of an enterprise i in period t, $EPU_{i,t-1}$ represents the economic policy uncertainty level of an enterprise i in period $(t-1)$, and $CDI_{i,t-1}$ represents the carbon information disclosure quality level of an enterprise i in period $(t-1)$. The control variables in the models are as follows: λ_i represents the time-fixed effects and μ_i represents the individual effects. If α_1 is substantially negative, economic policy uncertainty is negatively correlated with enterprise green innovation; otherwise, it is positively correlated, which verifies H1. If β_1 is significantly positive, the carbon information disclosure level is positively correlated with enterprise green innovation, thus verifying H2.

To verify the moderating effect in H3, carbon information disclosure level, on the impact of economic policy uncertainty on enterprise green innovation, a model was constructed, as follows:

$$EGI_{i,t} = \eta_0 + \eta_1 EPU_{i,t-1} + \eta_2 EPU_{i,t-1} \times CDI_{i,t-1} + \eta_3 CDI_{i,t-1} + \sum \eta_k \text{Control Variables} + \lambda_i + \mu_i + \varepsilon_{i,t} \quad (3)$$

where $\eta_2 EPU_{i,t-1} \times CDI_{i,t-1}$ is the intersection term of economic policy uncertainty and carbon information disclosure. Regardless of whether the correlation between enterprise green innovation and economic policy uncertainty is positive or negative, if the coefficient of this intersecting term is sufficiently positive, H3 is supported.

5. Empirical Test and Result Analysis

5.1. Description of Statistics

Descriptive statistics were calculated for the main variables, and the results are shown in Table 2.

Table 2. Descriptive statistics of model variables.

Variable Symbol	N	SD	Mean	Median	Max	Min
EGI	8637	8637	0.127	0.102	0.097	0.239
EPU	8637	0.892	1.948	1.706	3.648	0.823
CDI	8637	0.544	3.087	3	4	2
Size	8637	1.029	21.550	21.39	24.99	19.75
Prty	8637	0.252	0.53	1	1	0
Lev	8637	0.196	0.349	0.324	0.820	0.033
CF	8637	0.068	0.041	0.040	0.223	−0.163
Age	8637	5.703	7.729	6	27	2
Tz	8637	2.197	3.251	2.561	12.60	0.970
GDP	8637	1.390	7.965	7.800	14.20	6.700
Sg	8637	0.372	0.208	0.144	2.122	−0.432
ROE	8637	0.087	0.083	0.081	0.328	−0.287
FDI	8637	0.062	0.034	0.037	0.086	0.012
Area	8637	0.206	0.39	0	1	0

As shown in Table 2, we found significant variances in the green innovation input of different firms, where the average value of green innovation for enterprises was 0.102, the highest value was 0.169, the minimum value was 0.007, and the standard deviation was 0.127. The Economic Policy Uncertainty Index's mean value, maximum value, minimum value, and standard deviation were 1.948, 3.648, 0.823, and 0.892, respectively. This indicated that economic policy uncertainty substantially changed over the years covered in the sample, and the specific correlation between them was discussed and confirmed by the subsequent regression analysis. The average carbon information disclosure level was 3.087, indicating that most firms displayed a rather high level of carbon information sharing. The scale of the company index had an average value of 21.55, a maximum value of 24.99, a minimum value of 19.75, and a standard deviation of 1.029, indicating considerable scale variances across the sample enterprises that needed to be managed. The asset–liability ratio had an average value of 0.34, a maximum value of 0.82, a minimum value of 0.0329, and a standard deviation of 0.34. This wide range showed that differences remained in the asset–

liability ratio among businesses, which needs to be controlled. Investment opportunities had an average value of 3.251, a maximum value of 12.6, a minimum value of 0.97, and a standard deviation of 2.197. The standard deviation was 1.39, the maximum GDP growth rate was 14.2%, the minimum GDP growth rate was 6.7%, and the average GDP growth rate was 7.965%. We found notable variance between years that must be regulated. The mean of FDI was 3.4% and the median 3.7%, indicating that the overall foreign participation was not too high, but the difference was still remarkable and needs to be controlled.

5.2. Collinearity Verification

The developed model's dependability was assessed through a multiple regression analysis by using the Pearson correlation coefficient and variance inflation factor (VIF). The results of the Pearson correlation analysis and VIF are displayed in Tables 3 and 4, respectively.

Table 3. Correlation coefficients between variables.

Variable	EPU	CDI	Size	Lev	Age	Tz	CF	GDP	Sg	ROE	Prty	FDI	Area
EPU	1												
CDI	−0.001	1											
Size	0.152 ***	0.165 ***	1										
Lev	0.027 ***	−0.084 ***	0.534 ***	1									
Age	0.138 ***	−0.012	0.498 ***	0.422 ***	1								
Tz	0.05 ***	−0.006	−0.388 ***	−0.326 ***	−0.158 ***	1							
CF	0.023 **	0.165 ***	0.042 ***	−0.145 ***	0.040 ***	0.134 ***	1						
GDP	−0.485 ***	−0.057 ***	−0.269 ***	−0.095 ***	−0.289 ***	−0.08 ***	−0.055 ***	1					
Sg	0.068 ***	−0.007	−0.054 ***	−0.019 *	−0.064 ***	0.185 ***	−0.052 ***	−0.037 ***	1				
ROE	−0.033 ***	0.279 ***	0.034 ***	−0.165 ***	−0.148 ***	0.221 ***	0.317 ***	0.171 ***	0.017	1			
Prty	0.103 ***	0.217 ***	0.156 ***	−0.016 **	0.129 ***	−0.102 ***		0.089 ***	0.075 **	0.143	1		
FDI	−0.082 ***	0.077 ***	0.111 ***	−0.220 ***	−0.444 ***	0.093 ***	0.051 ***	0.209 ***	0.043 ***	0.243 ***	−0.163 ***	1	
Area	0.025 ***	0.182 ***	0.093 ***	0.212 ***	0.137 ***	0.265 ***	0.206 ***	0.234 ***	0.172 ***	0.107 ***	0.079 **	0.196 ***	1

Note: ***, **, and * indicate significant at the 1%, 5%, and 10% levels (two-tailed), respectively.

Table 4. VIF values of variables.

Variable	VIF	Tolerance
EPU	1.320	0.755
CDI	1.160	0.865
Size	2.140	0.466
Lev	1.640	0.611
Age	1.780	0.563
Tz	1.430	0.701
CF	1.170	0.854
GDP	1.590	0.631
Sg	1.050	0.951
ROE	1.410	0.709
Prty	1.490	0.687
FDI	1.630	0.741
Area	1.340	0.705
Mean	1.510	0.711

Table 3 demonstrates that the association between variables was not strong, where all correlation coefficients between variables were less than 0.8. However, the multicollinearity correlation coefficient test was not secure, so additional tests were required.

The variance inflation factors between explanatory and control variables were all less than 3.0, and the tolerance was significantly higher than 0.1, as indicated in Table 4. As a result, the multicollinearity issue was not present in the model developed in this study.

5.3. Regression Results

Because we used panel data in this study, to accurately select the regression model, the F, LM, and Hausman tests were conducted on the model before verifying each hypothesis. According to the results, a multiple regression analysis was conducted with the fixed-effects model.

5.3.1. Economic Policy Uncertainty and Enterprise Green Innovation Analysis

First, a multiple regression analysis was conducted on H1, and the results are shown in Table 5.

Table 5. Regression results of H1.

Variable	Coef.	Std. Err	*t*-Value	*p*-Value
EPU	−0.106 ***	0.022	−3.52	0.000
Size	0.626 ***	0.262	17.67	0.095
Lev	−0.104	0.314	−1.02	0.566
Age	0.043 ***	0.107	4.52	0.000
Tz	0.058 ***	0.036	3.59	0.000
CF	0.072	0.171	0.45	0.197
GDP	−0.089 **	0.103	−2.99	0.007
Sg	0.263 ***	0.025	10.56	0.000
ROE	0.956 ***	0.139	8.12	0.000
Prty	0.131 ***	0.101	1.29	0.154
Area	0.032 **	0.061	0.05	0.794
FDI	0.103 **	0.219	1.89	0.013
_cons	3.207 ***	0.816	3.76	0.000
Enterprise fixed effects	Yes			
Year fixed effects	Yes			
R^2	0.412	Number of obs	8637	
F	91.570	Prob > F	0.000	

Note: *** $p < 0.01$, ** $p < 0.05$.

The following regression results demonstrate that the coefficient between economic policy uncertainty and enterprise green innovation was −0.106, which was significant at the 1% level when other variables affecting enterprise green innovation had been controlled. This demonstrated that, all factors being equal, the degree of economic policy uncertainty negatively correlated with enterprise green innovation, supporting H1a. When economic policy is uncertain, companies struggle to communicate with investors, and more financial restrictions are in place, which have an impact on business investments in green innovation. Companies tend to be cautious and scale back their investments in green innovation when economic policy uncertainty is high.

The scale of the company and the coefficient for the listed years were both positive and significant at the 1% level, indicating that the larger the size of the company, the longer the listed duration and the larger the company's investment in green innovation, which is consistent with the findings reported by H. Lin and S.X. Zeng (2014) [44]. The nature of property rights was significant at the 1% level, which suggested that state-owned enterprises have a better ability to choose green innovation. The relationship between enterprise green innovation and GDP growth rate was inverse and significant at the 5% level, suggesting that when the economy is strong and when companies are profitable, corporations are less likely to pursue green innovation. At the 1% level, the coefficient of return on equity became positive and significant. Future profitability for a business will provide it with the ability and motivation to innovate. The growth rate of the sales coefficient was positive and significant at the 1% level, indicating that the company will continue to innovate and undergo reforms to increase the competitiveness of its goods and services. In agreement with the findings of mainstream studies conducted abroad, the investment opportunity coefficient was positive and substantial at the 1% level, demonstrating that businesses were relatively sensitive to investment possibilities. The foreign participation and area situation were both positive and significant at the 5% level, indicating that eastern cities and enterprises with more foreign participation were more likely to adopt green innovation behaviors.

5.3.2. Analysis of Carbon Information Disclosure and Enterprise Green Innovation

After the F, LM, and Housman tests, the fixed-effects model was used, and the regression results are shown in Table 6.

Table 6. Regression results of H2.

Variable	Coef.	Std. Err	*t*-Value	*p*-Value
CDI	0.073 ***	0.031	4.37	0.000
Size	0.639 ***	0.040	16.29	0.000
Lev	−0.112	0.113	−0.92	0.318
Age	0.052 ***	0.047	4.46	0.000
Tz	0.127 ***	0.053	3.68	0.000
CF	0.069	0.139	0.67	0.537
GDP	−0.076 ***	0.043	−3.62	0.018
Sg	0.285 ***	0.036	11.08	0.000
ROE	0.893 ***	0.246	7.84	0.000
Prty	0.123 ***	0.103	1.22	0.202
Area	0.026 **	0.001	0.07	0.000
FDI	0.082 **	0.037	1.63	0.018
_cons	3.068 ***	0.773	3.82	0.000
Enterprise fixed effects	Yes			
Year fixed effect	Yes			
R^2	0.409	Number of obs	8637	
F	92.420	Prob > F	0.000	

Note: *** $p < 0.01$, ** $p < 0.05$.

As shown in Table 6, the coefficient between the carbon information disclosure level and enterprise green innovation was 0.073 and significant at the 1% level, which supported H2. This indicated that when as many other influencing factors as possible were controlled, the higher the level of carbon information disclosure was, the greater amount of green innovation will occur. This is because a higher level of carbon information disclosure alleviates the moral hazard and agency problems caused by information asymmetry and increases enterprise green innovation.

5.3.3. Analysis of Carbon Information Disclosure on the Relationship between Economic Policy Uncertainty and Enterprise Green Innovation

After testing, we found that the fixed-effects model could still be used. The regression results of the carbon information disclosure level on the relationship between economic policy uncertainty and enterprise green innovation are shown in Table 7.

In this study, the product phase was created to test the impact of regulation. The three primary types of results were those obtained through the addition of control factors; those obtained through the addition of explanatory variables and moderating variables; and those obtained via the addition of an interaction term between the two centers.

By examining the significance of the interaction term or of the r-squared change, we can determine whether the moderating impact is substantial. The third column shows that the interaction term was significant at the 1% level, indicating that the influence of economic policy uncertainty on corporate green innovation was lesser for businesses with high levels of carbon information disclosure, supporting hypothesis H3a. The regulating effect was the weakening of the primary effect when the main effect was significantly negative, which was also confirmed by the partial derivative method:

$$\frac{\partial \mathrm{EGI}}{\partial \mathrm{Epu}} = \eta_1 + \eta_2 \mathrm{CDI}$$

where η_1 is negative and η_2 is positive in the result. When the quality of carbon information disclosure increased, that is, when CDI increased, the impact of economic policy uncertainty on enterprise green innovation weakened. Because the quality of carbon information disclosure increased, enterprises could obtain lower financing costs, which provided financial

support for the green innovation of enterprises, so that the green innovation behavior of enterprises could be enhanced.

Table 7. Regression results of H3.

Variable	EGI	EGI	EGI
EPU		−0.0472 ***	−0.0381 ***
		(−2.34)	(−2.73)
CDI		0.0734 ***	0.0677 ***
		(4.12)	(4.33)
EPU∗CDI			0.0289 ***
			(3.17)
Size	0.6263 ***	0.6386 ***	0.6372 ***
	(17.67)	(16.29)	(17.54)
Lev	−0.1042	−0.1124	−0.0963
	(−1.02)	(−0.92)	(−0.103)
Age	0.0428 ***	0.0515 ***	0.0508 ***
	(4.52)	(4.46)	(4.26)
Tz	0.0581 ***	0.0529 ***	0.0584 ***
	(3.59)	(3.69)	(3.71)
CF	0.0717	0.0687	0.0674
	(0.45)	(0.67)	(0.47)
GDP	−0.0887 ***	−0.0764 ***	−0.0767 ***
	(−2.99)	(−3.62)	(−3.09)
Sg	0.2627 ***	0.2842 ***	0.2637 ***
	(10.56)	(11.08)	(10.67)
ROE	0.9564 ***	0.8927 ***	0.8875 ***
	(8.12)	(7.84)	(6.39)
Prty	0.1312 ***	0.1227 ***	0.1244 ***
	(1.29)	(1.22)	(1.24)
Area	0.0322 **	0.0264 **	0.0274 **
	(0.05)	(0.07)	(0.08)
FDI	0.1034 **	0.0824 **	0.0847
	(1.89)	(1.63)	(1.73)
_cons	3.2074 ***	3.0683 ***	3.2981 ***
	(3.76)	(3.82)	(3.77)
Enterprise fixed effects	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
N	8637	8637	8637
F	91.5697	92.4204	94.1286
Adj-R^2	0.411	0.4083	0.414
R^2	0.4123	0.4091	0.4178

Note: *** $p < 0.01$, ** $p < 0.05$.

Group regression was used to further analyze the moderating effect proven above. The samples were divided into two groups: those with a high level of carbon information disclosure (Id = 1) and those with a low level of carbon information disclosure (Id = 0), and the regression between enterprise green innovation and economic policy uncertainty was conducted, separately. The regression results are shown in Table 8.

Table 8 shows that in the low carbon information disclosure group, the coefficient of economic policy uncertainty was negative and significant at the 1% level in the high carbon information disclosure level group; the coefficient was negative but insignificant. This indicated that the level of carbon information disclosure played a weakening role in the impact of economic policy uncertainty on enterprise green innovation, which further corroborated the test results for the above moderating effect.

Table 8. Results of grouped regression.

Variable	CDI = 0 EGI	CDI = 1 EGI
EPU	−0.1360 *** (−3.05)	−0.0131 (−1.48)
Size	0.7042 *** (5.17)	0.6039 *** (17.78)
Lev	−1.2108 ** (−2.13)	0.0362 (0.31)
Age	0.126 ** (2.23)	0.0626 *** (4.48)
Tz	−0.0104 (−0.14)	0.0275 *** (3.96)
CF	0.2301 (0.35)	−0.0190 (−0.16)
GDP	−0.0656 (−0.18)	−0.0283 ** (−2.55)
Sg	0.3216 *** (3.39)	0.2329 *** (10.83)
ROE	0.2348 (0.71)	0.9046 *** (5.38)
Prty	0.172 ** (0.02)	0.617 *** (2.93)
Area	0.068 * (0.12)	0.006 (0.12)
FDI	0.0101 (1.43)	0.0006 (0.44)
_cons	1.4963 (0.50)	3.7759 *** (5.20)
Enterprise fixed effects	Yes	Yes
Year fixed effect	Yes	Yes
N	937	7700
F	6.3230	89.7134
Adj-R^2	0.327	0.517
R^2	0.3390	0.5181

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$; t values are in parentheses.

5.3.4. Test for Robustness

To verify the robustness of economic policy uncertainty and carbon information disclosure on the estimation results of enterprise green innovation, we performed a substitution of variables, and we replaced the ratio of enterprise green innovation investment to enterprise total revenue with the enterprise green innovation patent situation for testing. The number of enterprise green innovation patents was quantified by adding one natural logarithm to the number of green patents [42], and the test results are shown in Table 9.

Table 9. Robustness test results of change in green innovation measurement index.

Variables Symbol	EGI	EGI	EGI
EPU	−0.1164 *** (−2.48)		−0.1408 *** (−2.43)
CDI		0.2041 *** (1.85)	0.2208 *** (1.37)
EPU∗CDI			0.1147 *** (2.25)
_cons	5.4672	5.2639	5.3305
Controls	Yes	Yes	Yes
Enterprise fixed effects	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
N	8637	8637	8637
F	18.2077	17.5484	17.2405
Adj-R^2	0.405	0.443	0.387
R^2	0.403	0.451	0.385

Note: *** $p < 0.01$; t values are in parentheses.

Table 9 shows that even with the variables replaced, each variable's significance and sign still matched those of the original model, demonstrating the excellent stability and reliability of the model that we developed in this study.

6. Conclusions and Prospects

We investigated the relationship between economic policy uncertainty, carbon information disclosure, and corporate green innovation through an analysis of sample businesses. We also examined the moderating impact of the level of carbon information disclosure on the influence of economic policy uncertainty on corporate green innovation. The following findings were reached:

(1) A strong inverse relationship exists between enterprise green innovation and economic policy uncertainty. This is in line with both real option theory and the information asymmetry hypothesis. Investments in green innovations become riskier as economic policy uncertainty grows, and management is more willing to wait and watch [45,46]. Decision-making also becomes more challenging. Enterprises in the external environment lack judgment and understanding, and the lack of external funding reduces businesses' ability to raise the money necessary for innovation, forcing them to scale back [47].

(2) A strong positive association exists between enterprise green innovation and the quality of carbon information disclosure. Information asymmetry lessens, and the cost of borrowing decreases when the carbon information disclosure level is high. Additionally, it can lower management's rent-seeking behavior, bring in more funding for the company's green innovation [48], and raise the level of green innovation within the company.

(3) The degree of carbon information transparency weakens the link between enterprise green innovation and the unpredictability of economic policy. Because of the unique characteristics of each business, the effects of unclear economic policy on green business innovation vary. Because they offer comparatively extensive and high-quality information, businesses with a high degree of carbon information disclosure are more likely to be favored by external financial institutions [49]. With uncertain economic policies, quality carbon information disclosure deters some cautionary management practices, practices such as lowering investment in green innovation. All these factors reduce the effect of unclear economic policy on corporate green innovation in businesses with high levels of carbon information disclosure.

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