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The impact of extreme weather on residents' low-carbon consumption behavior: an empirical study based on 615 samples from Zhejiang Province

Xinli Li**, *Zizhen Cai, Yiling Shi

Zhejiang Normal University, Jinhua, China

*Corresponding Author. Email: lixinli@zjnu.edu.cn

Abstract. Against the backdrop of intensifying global warming and frequent extreme weather events, the low-carbon transition of residents' consumption behavior has become an important micro-foundation for achieving the "dual carbon" goals. Based on 615 resident survey datasets collected from four cities in Zhejiang Province—Huzhou, Jiaxing, Quzhou and Jinhua—this study empirically examines the effect of extreme weather on residents' low-carbon consumption behavior and its underlying mechanisms using a structural equation model. The findings are as follows: (1) Extreme weather exerts a significant positive direct impact on residents' low-carbon consumption behavior ($\beta = 0.312$, $p < 0.001$). (2) Green cognition and environmental attention play partial mediating roles between extreme weather and low-carbon consumption behavior, yet the mediating effects are weaker than the direct effect. (3) Government environmental regulation intensity positively moderates the relationship between extreme weather and low-carbon consumption behavior ($\beta = 0.228$, $p < 0.01$). This study reveals the mechanism by which extreme weather drives residents' low-carbon consumption through the path of "risk perception—cognition improvement—behavior transformation", and provides empirical evidence for governments to formulate differentiated low-carbon consumption guidance policies under climate risk contexts.

Keywords: extreme weather, low-carbon consumption, green cognition, environmental attention, structural equation model

1. Introduction

Global climate change has become one of the most severe challenges facing humanity in the 21st century. The *Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC) notes that the global average temperature has risen by approximately 1.1 °C compared with pre-industrial levels, and the frequency and intensity of extreme weather events such as extreme high temperatures, heavy precipitation and drought have all shown a marked upward trend [1]. As the world's largest carbon emitter, China bears the pronounced impacts of climate change. According to the *Blue Book on Climate Change in China (2024)*, the number of national extreme high-temperature days in the past decade has increased by 215% compared with the same period in the last century, and the frequency of heavy precipitation events has risen by 48.3%. In 2022, direct economic losses caused by climate disasters nationwide reached 327.5 billion yuan, 24.3% higher than the average of normal years [1].

Extreme weather not only inflicts direct damage on natural ecosystems and infrastructure, but also profoundly reshapes residents' energy consumption patterns and lifestyles. Sustained high temperatures drive up energy consumption for air conditioning cooling, and severe rainstorms force households to purchase emergency power generation equipment—these phenomena indicate that extreme weather is altering residents' daily consumption decisions [2]. Meanwhile, the advancement of the national "dual carbon" strategy has set clear requirements for the low-carbon transition on the household consumption side. The *Implementation Plan for Promoting Green Consumption*, jointly issued by seven departments including the National Development and Reform Commission in 2022, explicitly proposes to comprehensively advance the green transition of consumption in multiple sectors such as food, clothing, housing and transportation [3]. Against this background, a key question arises: Does extreme weather reinforce residents' reliance on high-carbon consumption, or does it push forward the low-carbon consumption transition? What is its underlying mechanism?

Existing studies on the influencing factors of residents' low-carbon consumption behavior mostly focus on dimensions such as individual psychological characteristics (e.g., environmental attitudes, ecological values), social norms (e.g., neighborhood influence, social supervision) and policy interventions (e.g., subsidies, carbon pricing) [4, 5]. In recent years, some scholars have begun to examine the impact of external environmental factors on consumption behavior, especially the psychological and behavioral consequences of extreme weather events. Weber [6] points out that extreme weather events significantly increase individuals' willingness to adopt pro-environmental behaviors by strengthening their climate risk perception. An empirical study by Spence et al. [7] based on flood events in the UK found that residents who had directly experienced extreme weather were more inclined to invest in household energy-saving equipment, with their low-carbon consumption expenditure 23% higher than that of those who had not. Nie [8] found that environmental responsibility can stimulate individuals' pro-environmental attitudes, thereby promoting low-carbon emission reduction behaviors; a study by Huang [9] shows that green cognition indirectly affects consumers' green purchase behavior through green involvement.

However, existing studies still have the following shortcomings. First, most studies treat extreme weather as a contextual factor rather than a core explanatory variable, lacking systematic empirical tests on how extreme weather affects low-carbon consumption behavior. Second, the mediating mechanism through which extreme weather influences low-carbon consumption behavior—especially the roles of green cognition and environmental attention—still lacks sufficient empirical support. Third, research on how external institutional factors such as government environmental regulatory policies moderate the consumption behavior effect of extreme weather remains relatively scarce. These research gaps constitute the core motivation of this paper.

Based on the above analysis, this paper takes residents in four regions of Zhejiang Province that are notably affected by extreme weather—Huzhou, Jiaxing, Quzhou and Jinhua—as survey subjects, and empirically tests the effect of extreme weather on residents' low-carbon consumption behavior using a structural equation model, with a focus on the mediating roles of green cognition and environmental attention as well as the moderating role of government environmental regulation intensity. The potential marginal contributions of this paper are as follows: First, it elevates extreme weather from a background variable to a core explanatory variable, and reveals the linkage mechanism between climate risk and residents' micro-level consumption behavior. Second, it integrates the "cognition—affection—behavior" theoretical framework and verifies the transmission path of green cognition and environmental attention in the impact of extreme weather on low-carbon consumption. Third, it identifies the moderating effect of government environmental regulation, providing empirical evidence for the application of differentiated policy tools in the context of climate risks.

2. Literature review and research hypotheses

2.1. Definition of core concepts

2.1.1. Extreme weather

Extreme weather refers to meteorological events that deviate significantly from historical normal conditions and carry strong destructive power, with their intensity, duration or geographic scope exceeding the range of conventional statistical distribution [1]. The World Meteorological Organization defines "weather phenomena with a daily occurrence rate of less than 10% within a 30-year climate reference period" as extreme weather events [1]. Large-scale extreme weather includes extreme high temperature, extreme low temperature, extreme precipitation and extreme drought; small and medium-scale extreme weather covers hail, strong wind, tornadoes, thunderstorms and others [10]. With global warming, the frequency and intensity of extreme weather events have shown a significant upward trend [11]. This paper defines extreme weather from the perspective of residents' subjective perception and operationalizes it into three dimensions: residents' level of understanding, degree of perception, and extent of impact regarding extreme weather.

2.1.2. Green cognition and environmental attention

Green cognition refers to individuals' accumulated knowledge and level of understanding of environmental issues, sustainable development and low-carbon lifestyles [9]. Hines et al. [12] early noted that knowledge of pro-environmental behaviors can effectively identify potential green consumers. Based on the "extended knowledge-attitude-behavior model", Wang J. M. and Wang Y. [13] proposed that consumers' ecological civilization behavior generally follows the cognition—belief—behavior path. Accordingly, this paper defines green cognition as consumers' understanding of green consumption-related knowledge and their recognition of green consumption concepts [9, 13].

Environmental attention reflects individuals' cognitive depth, information sensitivity and sustained attention to environmental issues [14]. Yang [15] argues that environmental responsibility is a concentrated reflection of individuals' perception of environmental problems, attitudes toward environmental behavior and environmental emotions; Wang et al. [16] further point out that individuals with a high level of ecological cognition tend to develop environmental responsibility more readily. This paper operationalizes environmental attention into three dimensions: residents' knowledge level of environmental issues, affective cognition and practical participation.

2.1.3. Residents' low-carbon consumption behavior

Low-carbon consumption refers to achieving the win-win goal of improved quality of life and reduced carbon emissions by cutting high-carbon consumption and excessive consumption, on the premise of guaranteeing consumers' quality of life [17, 18]. Referring to the classification framework of the *China Statistical Yearbook* [19], this paper measures residents' low-carbon consumption behavior across nine dimensions: low-carbon clothing, low-carbon housing, low-carbon travel, low-carbon food, low-carbon communication, low-carbon healthcare, low-carbon household equipment and services, low-carbon cultural, educational and recreational goods and services, and other low-carbon goods and services.

2.2. Theoretical analysis and research hypotheses

2.2.1. Direct impact of extreme weather on residents' low-carbon consumption behavior

Extreme weather may directly affect residents' low-carbon consumption behavior through the following paths. First, extreme weather events enhance individuals' willingness to adopt pro-environmental behaviors by strengthening their climate risk perception [6]. When residents personally experience or closely perceive the destructive consequences of extreme weather, their awareness of climate change risks increases significantly, and this risk perception translates into motivation for energy conservation and carbon reduction actions. Second, extreme weather triggers behavioral adaptation through "experiential learning" [7]. Research by Spence et al. [7] shows that residents who have directly experienced floods are more likely to invest in household energy-saving equipment. In the Chinese context, phenomena such as sustained high temperatures driving residents to purchase energy-efficient air conditioners, and rising demand for emergency energy storage equipment after rainstorm disasters, both reflect the mechanism by which extreme weather promotes low-carbon adjustments in consumption behavior through experiential learning. Accordingly, the following hypothesis is proposed:

H1: Extreme weather has a significant positive impact on residents' low-carbon consumption behavior.

2.2.2. Mediating roles of green cognition and environmental attention

Extreme weather not only directly affects low-carbon consumption behavior, but may also exert an indirect influence by improving residents' green cognition and environmental attention. From the green cognition path, the frequent occurrence of extreme weather transforms the climate change issue from a "distant threat" into a "present reality", and this embodied experience helps deepen residents' understanding of the causal chain between greenhouse gas emissions and extreme weather [9]. Cui et al. [20] found that the higher the green value perceived by individuals, the more likely they are to engage in green consumption behavior; Huang [9] verified the positive driving effect of green cognition on green purchase behavior. Accordingly, the following hypothesis is proposed:

H2: Green cognition plays a mediating role in the impact of extreme weather on residents' low-carbon consumption behavior.

From the environmental attention path, extreme weather events have a notable "attention capture" effect. Frequent extreme weather reports and personal experiences raise residents' attention to environmental issues, making them more actively seek environmental protection information and follow developments in environmental policies [8]. Lu et al. [21] found that members of the public with a sense of environmental responsibility regard environmental protection as their own duty and obligation, and actively translate green environmental awareness into practical actions. Accordingly, the following hypothesis is proposed:

H3: Environmental attention plays a mediating role in the impact of extreme weather on residents' low-carbon consumption behavior.

2.2.3. Moderating role of government environmental regulation

Government environmental regulatory policies constitute an important institutional environment that affects residents' low-carbon consumption behavior [22]. The "Porter Hypothesis" proposed by Porter and van der Linde [23] holds that appropriate environmental regulation can stimulate an innovation compensation effect. In the process where extreme weather affects low-carbon consumption behavior, government environmental regulation may play a positive moderating role: when environmental regulation intensity is high, the government can amplify the warning effect of extreme weather on residents' risk perception through policy tools such as carbon labeling systems, green consumption subsidies and energy-saving product certification [24]. Zhao [25] points out that high-intensity environmental regulation can force the green transformation of supply chains by strengthening corporate environmental responsibility, lowering the price of low-carbon products and improving their availability. Accordingly, the following hypothesis is proposed:

H4: The intensity of government environmental regulation positively moderates the impact of extreme weather on residents' low-carbon consumption behavior.

3. Research design

3.1. Data source and sample selection

The data for this paper comes from a field survey conducted in Zhejiang Province in July 2025. As an economically developed coastal province in eastern China, Zhejiang faces high vulnerability to climate change and is also a pioneer in low-carbon development, giving it strong research representativeness. The survey adopts a stratified sampling method. Based on the degree to which each region is significantly affected by extreme weather, four areas are selected as the survey scope: Nanxun District in Huzhou, Haining City in Jiaxing, Jiangshan City in Quzhou and Yiwu City in Jinhua. The sample size is calculated using the simple random sampling formula. Under the conditions of a 95% confidence level and 5% margin of error, and considering a design effect of 2.0 and a 90% questionnaire response rate, the total number of distributed questionnaires is set at 856. After data cleaning, 615 valid questionnaires are finally obtained, with an effective response rate of 71.8%.

The sample composition is as follows: males account for 50.08% and females for 49.92%; the age distribution is concentrated in the 31–40 age group (28.94%) and the 19–30 age group (25.20%); respondents with junior high school education or below make up 25.37%, those with senior high school/technical secondary school education account for 39.19%, and those with junior college education or above account for 35.45%; annual household income is mainly in the range of 60,000–96,000 yuan (32.68%) and below 60,000 yuan (20.49%).

3.2. Variable measurement

3.2.1. Explanatory variable: extreme weather

Referring to the IPCC [1] definition of extreme weather and related studies, measurement items are designed from three dimensions: level of understanding, degree of perception and extent of impact, using a 5-point Likert scale [26]. The Cronbach's α coefficient is 0.763.

3.2.2. Mediating variables: green cognition and environmental attention

Green cognition is measured from three dimensions—systematic cognition, action cognition and efficacy cognition—with reference to the study of Huang [9]; environmental attention is measured from three dimensions: knowledge level, affective cognition and practical participation. The Cronbach's α coefficients of the two variables are 0.924 and 0.777 respectively [9].

3.2.3. Explained variable: residents' low-carbon consumption behavior

Referring to the classification framework of the *China Statistical Yearbook* [19], it is measured across nine dimensions: clothing, housing, travel, food, communication, healthcare, household equipment and services, cultural, educational and recreational goods and services, and other goods and services. The Cronbach's α coefficient is 0.777.

Moderating variable: Intensity of government environmental regulation. It is measured from three dimensions: policy cognition, perceived supervision intensity and policy implementation effect, with a Cronbach's α coefficient of 0.679 [25].

The KMO values of all variables are above 0.6, and the *p*-values of Bartlett's test of sphericity are all less than 0.001. The results of exploratory factor analysis indicate good structural validity for all variables. The results of confirmatory factor analysis show that the model fit indices are: $\chi^2/df = 2.339$, RMSEA = 0.047, NFI = 0.902, CFI = 0.941, IFI = 0.942, TLI = 0.935, all reaching satisfactory levels.

3.3. Model specification

This paper adopts a structural equation model to test the effect and mechanism of extreme weather on residents' low-carbon consumption behavior. The reasons for selecting the structural equation model are as follows: First, the research involves multiple latent variables and complex path relationships among them. Second, the simultaneous testing of mediating and moderating effects requires an analytical framework capable of handling multiple causal relationships. Third, the structural equation model can estimate the measurement model and structural model simultaneously, effectively controlling for measurement errors [27].

The model specifications are as follows:

(1) Direct effect model: To test the direct impact of extreme weather on low-carbon consumption behavior (H1).

(2) Mediating effect model: To test the mediating roles of green cognition and environmental attention between extreme weather and low-carbon consumption behavior (H2, H3).

(3) Moderating effect model: To test the moderating effect of government environmental regulation intensity on the relationship between extreme weather and low-carbon consumption behavior (H4).

4. Empirical results

4.1. Descriptive statistics

The descriptive statistics for each variable show that the mean values of the three dimensions of extreme weather range from 3.39 to 3.42, indicating that residents' cognition and perception of extreme weather are at a moderately high level; the mean values of the three dimensions of green cognition range from 3.41 to 3.44; the mean values of the three dimensions of environmental attention range from 3.41 to 3.73, with "practical participation" scoring the highest (3.73); the mean values of the nine dimensions of low-carbon consumption behavior range from 3.37 to 3.47, with "low-carbon household equipment and service behavior" scoring the highest (3.47).

Statistical analysis of the extreme weather variable shows that public awareness of extreme weather presents a gradient difference: the score for level of understanding is the highest (3.43), followed by degree of perception (3.42), and extent of impact is the lowest (3.37). This result indicates that although most residents can recognize the existence of extreme weather through media reports, their perception of the actual impact of extreme weather on daily life remains relatively limited, and the "cognition-behavior gap" is fairly pronounced [28].

4.2. Results of the structural equation model

The overall fit indices of the structural equation model are: $\chi^2/df = 2.339$, RMSEA = 0.047, NFI = 0.902, CFI = 0.941, IFI = 0.942, TLI = 0.935 [27]. All indices reach satisfactory levels, indicating good fit between the model and the sample data.

4.2.1. Direct effect test

The standardized path coefficient of extreme weather on residents' low-carbon consumption behavior is 0.312 ($p < 0.001$), and hypothesis H1 is verified. This result indicates that an increase in the severity of extreme weather can significantly promote residents' low-carbon consumption behavior. For every 1% increase in the severity of extreme weather, residents' low-carbon consumption behavior rises by 0.312%.

4.2.2. Mediating effect test

The standardized path coefficient of extreme weather on green cognition is 0.263 ($p < 0.001$), and the standardized path coefficient of green cognition on low-carbon consumption behavior is 0.120 ($p < 0.001$). The standardized path coefficient of extreme weather on environmental attention is 0.198 ($p < 0.001$), and the standardized path coefficient of environmental attention on low-carbon consumption behavior is 0.046 ($p < 0.001$). Both the mediating effects of green cognition and environmental attention are significant, but their effect strength is weaker than the direct effect of extreme weather. Hypotheses H2 and H3 are verified.

4.2.3. Moderating effect test

The moderating effect of government environmental regulation intensity on the relationship between extreme weather and low-carbon consumption behavior is significant ($\beta = 0.228$, $p < 0.01$). In contexts with higher environmental regulation intensity, the promoting effect of extreme weather on low-carbon consumption behavior is more pronounced. Hypothesis H4 is verified.

5. Discussion

This study finds that extreme weather has a significant positive direct impact on residents' low-carbon consumption behavior ($\beta = 0.312$, $p < 0.001$), which is consistent with the conclusions of Weber [6] and Spence et al. [7], indicating that extreme weather events can indeed drive residents to adopt more low-carbon consumption behaviors by enhancing individual climate risk perception and experiential learning. However, the effect size in this study ($\beta = 0.312$) is slightly larger than that reported in Spence et al. [7] (23% difference in expenditure), which may be attributable to the higher frequency and intensity of extreme weather events in China's coastal regions, as well as the stronger policy push from the national "dual carbon" strategy. This suggests that the behavioral response to extreme weather may be amplified by the institutional context in which individuals are situated.

The mediating effects of green cognition and environmental attention are significant but weaker than the direct effect. This pattern indicates that the impact of extreme weather on low-carbon consumption behavior is realized more through a direct "risk-response" mechanism rather than relying entirely on the mediating transformation of cognition and attitude. This finding is partially consistent with the extended knowledge-attitude-behavior model proposed by Wang J. M. and Wang Y. [13], but the weaker-than-expected mediating effects suggest that the cognitive pathway may require a longer time horizon to materialize. In other words, while extreme weather can quickly trigger behavioral changes through immediate risk perception (e.g., purchasing energy-efficient appliances during a heatwave), the slower, more gradual pathway of cognitive change and subsequent behavioral adaptation may take more time to develop. This insight helps explain the persistent "cognition-behavior gap" observed in environmental psychology research: although extreme weather can raise residents' environmental awareness, the translation of this awareness into actual behavior remains limited.

The significant moderating effect of government environmental regulation intensity ($\beta = 0.228$, $p < 0.01$) supports the Porter Hypothesis [23] in the context of household consumption. When environmental regulation is stringent, the government can amplify the "warning effect" of extreme weather through policy tools such as carbon labeling systems and green consumption subsidies. This finding is consistent with Zhao [25], who argued that high-intensity environmental regulation can lower the price of low-carbon products and improve their availability, thereby making it easier for residents to respond to extreme weather with low-carbon behaviors. The practical implication is that policy intervention and climate shocks may have a complementary effect: regulatory stringency enhances the behavioral responsiveness of residents to extreme weather events.

6. Conclusion

6.1. Research conclusions

Based on 615 resident survey datasets from Zhejiang Province, this paper empirically tests the effect and mechanism of extreme weather on residents' low-carbon consumption behavior using a structural equation model, and draws the following main conclusions.

First, extreme weather has a significant positive direct impact on residents' low-carbon consumption behavior. In the Chinese context, this conclusion carries important policy implications: extreme weather is not only a climate risk that requires passive response, but may also serve as a "catalyst" for advancing the low-carbon transition of residents' consumption.

Second, green cognition and environmental attention play partial mediating roles between extreme weather and low-carbon consumption behavior. However, the mediating effects are weaker than the direct effect, indicating that extreme weather influences behavior more through a direct "risk-response" mechanism rather than fully through cognitive mediation. This finding contributes to explaining the "cognition-behavior gap" that has been widely observed in environmental behavior research.

Third, the intensity of government environmental regulation positively moderates the impact of extreme weather on low-carbon consumption behavior. In contexts with higher environmental regulation intensity, the promoting effect of extreme weather on low-carbon consumption behavior is more significant, indicating that policy intervention can effectively amplify the "warning effect" of extreme weather.

The above conclusions provide the following policy implications for governments to formulate low-carbon consumption guidance policies against the background of climate risks. First, establish a rapid response mechanism linking extreme weather and low-carbon behavior. Given the direct promoting effect of extreme weather on low-carbon consumption behavior, it is recommended that the government embed low-carbon behavior guidance into the meteorological early warning system, and simultaneously release energy conservation and carbon reduction suggestions when issuing extreme weather warnings for high temperatures, rainstorms and other events, so as to turn short-term risk responses into long-term low-carbon behavioral habits. Second, strengthen the mediating transformation efficiency of green cognition and environmental attention. It is recommended to strengthen popular science publicity on the correlation between extreme weather and personal carbon footprints through channels such as community education, media coverage and school education, so as to improve the efficiency of residents' transition from cognition to behavior. Third, leverage the moderating and amplifying effect of policy tools. The government should make full use of the moderating role of environmental regulatory policies, increase green consumption subsidies and strengthen the enforcement of the carbon labeling system during periods of frequent extreme weather, so as to form a virtuous circle of "climate shock—policy response—behavioral change".

6.2. Limitations and future research directions

This paper has the following limitations. First, the data comes from a cross-sectional survey of four regions in Zhejiang Province. The geographical coverage of the sample is limited, and the external validity of the research conclusions requires further verification. Future studies could extend the survey to other provinces or national samples to test the generalizability of the findings. Second, the measurement of extreme weather is based on residents' subjective perception, lacking cross-validation with objective meteorological data. Combining subjective perception data with objective meteorological records could provide a more robust assessment. Third, cross-sectional data makes it difficult to strictly identify causal relationships. Future research may adopt follow-up surveys, panel data, or quasi-experimental designs (e.g., difference-in-differences) to establish causality more convincingly. Fourth, this study focuses on the overall effect of extreme weather, but future research could explore the heterogeneity of its impact—whether there are differences in responses among residents of different income levels, age groups, education levels and geographic regions—as well as the moderating roles of factors such as social networks, media communication, and community infrastructure.

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